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The Irreversible Welfare Cost of Climate Anomalies. Evidence from Japan (1872-1917)

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Abstract

This paper presents evidence of the irreversible consequences of exogenous climatic shocks and economic fluctuations on human welfare. We rely on a unique data set covering the period from 1872 to 1917, corresponding to the early phase of Japanese industrialization. This data includes prefecture level average temperature, precipitation, agricultural prices, and the number of individuals by interval of height recorded in conscription reports, as well as nationwide indices of fluctuation in economic activities. We estimate the impact of yearly and monthly regional climate anomalies and yearly nationwide business cycle reversals on the average height of Japanese conscripts and its dispersion.

Keywords: Business cycles, climate shocks, human stature, height cycles, Japan.

JEL Classification: E32, I15, N15, N95, Q54

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1. Introduction

Climate change may be expected to thrust more than 720 million people into poverty by 2050 and may drive up to 140 million people to become climate refugees (Rigaud et.al, 2018). Climate change is expected to generate not only a rise in long-term average temperature levels, but also higher amplitude and frequency of climate anomalies and extreme events (Giannakopoulos et al. 2005, Parry et al. 2007, IPCC 2013). Assessing the magnitude of the long-run socioeconomic effects of rising global temperature and climate anomalies has thus become an important goal (e.g. Mendelson, Nordhaus, and Shaw 1994; Deschêne and Greenstone 2007; Tol 2009; Dell, Jones and Olken 2012, 2014; Burke, Hsiang and Miguel 2015; Moore and Diaz 2015; Burzyński et al. 2019)[1], one which poses a number of challenges pointing to the need to include factors other than monetary estimates in the analytical framework.

Monetary estimates alone do not allow us to grasp the full spectrum of the consequences of climate anomalies on welfare, especially in developing nations. Such estimates are biased towards reversible costs given that drops in present income can be compensated by future monetary earnings. By contrast, sizeable climate anomalies may undermine human health and cognitive skills, and hence irreversibly lower the welfare of affected individuals. In particular, recent studies have provided evidence of the impact of temperatures anomalies on mortality (Deschênes and Greenstone 2011; Barreca et al. 2015) and on cognitive performance in mathematics (Graff Zivin, Hsiang and Neidell 2018).

In addition, monetary estimates tend to conceal potentially significant distributional effects, given that the impact of a drop in monetary income on real welfare is higher for the lower income segment of the population. Support for this hypothesis can be found in the literature on welfare cost of economic fluctuations, which indicates that individuals experience macroeconomic reversals differently depending on their income level (Pallage and Robe 2003; Mukoyama and Sahin, 2006; Krusell et al, 2009, Ho, Ho and Li, 2010)[2]. Properly measuring the

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[1] The combined effects of natural disaster (including non-climate related events such as earthquakes, and tsunamis) have recently been estimated as equivalent to a $520 billion drop in consumption (Hallegatte et.al, 2017). Such catastrophic events disrupt the economy by increasing consumer prices, reducing economic opportunities, and depleting financial, human, natural, and social assets (Hallegate et.al, 2014, 2017).

[2] The welfare implications of economic fluctuations have been the object of much debate during the past decades. The debate has opposed authors such as Lucas (1987) and Otrok (2001), who describe the gain of removing business cycles as negligible for most agents, to others arguing that the gain could be substantial for most, e.g.

permanent impact of climate anomalies on the poor would require us to rely on alternative non-monetary welfare indicators. It also entails the adoption of a long-run perspective, given that permanent effects are, by definition, experienced throughout the entire lifespan of the affected cohort.

The approach we follow in this paper adopts a historical perspective to complement the existing literature on the economic consequences of climate change which relies mostly on contemporaneous case studies for higher-income countries or scenario-based modelling (e.g. Winter et al. 1998; Bosello, Roson and Tol 2006; Deschênes and Greenstone 2007; Hallegate et al 2015; Lobell and Asseng 2017). We investigate the permanent impact of climate anomalies on height in late 19th and early 20th century Japan, which was at that time a lower-income developing country. Our estimates indicate that climate anomalies during gestation and early infancy induce a decrease in average height observed at adulthood, as well as an increase in height dispersion, indicating that climate shocks result in greater inequalities in permanent welfare.

Our approach is rooted in the human welfare literature (Steckel 2009). It is well established that long-term trends in average stature are determined by changes in economic conditions, due to the link between income and environmental conditions, in particular nutritional status and health conditions from gestation to adulthood (Banerjee et.al, 2010; Steckel 1995; Deaton 2008; Chen and Zhou 2007; Gørgens, Meng and Vaithianathan 2012; Sven Neelsen and Stratmann 2011). A significant inter-relation has also been observed between short term business cycle reversals (as measured by macroeconomic indicators of income, output, or investment) and cycles in human stature (Woitek 2003; Jacobs and Tassenaar 2004; Brabec 2005; Sunder and Woitek 2005)[3]. Finally, height dispersion is closely related to income distribution and its dispersion is, indeed, a possible proxy for the historical value of Gini coefficients of income and a measure of personal inequality (Van Zanden et al., 2014)[4]. The present study makes an

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Barlevy (2004). At an empirical level, micro-data studies are restricted to higher-income countries, in particular the United States. Although Krusell and Smith (1999) find that the welfare cost of business cycles is small for all agents, and even negative for a few of them, other studies reveal a different distribution (Storesletten, Telmer and Yaron, 2001). Mukoyama and Sahin (2006) find that unskilled workers benefit from removing business cycles more than skilled ones, and Krusell et al (2009) identify gains for very poor and very rich consumers, while the majority of the consumers with intermediate income do not benefit much. Imrohoroglu (2008) offers a comprehensive presentation of these debates.

[3] These fluctuations in human stature are not harmonic waves with fixed frequency and amplitude, but akin to economic fluctuations that are commonly described as business cycles. It is therefore acceptable to describe these phenomena as height cycles.

[4] Quantitative analyses using international or inter-regional cross-section data highlight the role of other explanatory variables such as availability of health services, urbanization, and the workload of children and pregnant women (Steckel 1995, 2009). However, we focus on the impact of exogenous shocks and therefore do not take these variables into account given that they tend to evolve at a relatively slow pace.

original contribution to this literature by using anthropometric indicators, height and height dispersion, to assess the welfare cost of exogenous climate shocks.

We focus on Japan during the early phase of its industrialization (i.e., from 1872 to 1917). We believe that Japan has a number of distinctive features making it an ideal case study for the purpose of our investigation. At the turn of the 20th century, Japanese average per capita income was low by European standards: at the country level, per capita GDP in 1874 was 1013 $ international dollars at constant prices of 1990, rising to 1166 $ in 1890 and 1467 $ in 1909.[5] Japan was also still an agrarian economy[6], in which rural households were vulnerable to crop failures triggered by climate anomalies (such as abnormal summer temperatures during rice blossoming, drought in winter or spring, or floods in summer and early autumn). For most Japanese households, foodstuffs indeed accounted for a sizable share of consumption in the late 19th and early 20th century[7]. Finally, focusing on a pre-industrial, pre-climate change time period will provide a conservative estimate of the magnitude of climate anomalies.

We rely on a unique database developed based on army records and calculated at the regional level (47 prefectures). This database allows us to measure average as well as the coefficient of variation of height for 20-year-old Japanese conscripts born in 1872-1917. We also rely on monthly prefecture level weather records to measure climate anomalies in temperature and precipitation. Finally, we consider the potential effects of the country-level macroeconomic events in the non-agrarian sector and control for regional prices of basic crops (rice, soy, barley) using available high-quality historical economic data. Our methodology combines spectral analysis, fixed-effect panel regressions, examination of cumulative orthogonalized impulse response and dynamic multipliers of PVAR-X models, as well as a set of simulations. All tests indicate that economic and climatic shocks generate detrimental short-term deviations in the mean and the dispersion of stature. Further, the identified effects appear credible in size.

The remainder of the paper is structured as follows. Section 2 presents our anthropometric dataset. Section 3 discusses the possible influence of climate anomalies on height and presents our climate data. Section 4 examines the correlation between business cycles and height cycles

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[5] (Settsu, Fukao and Bassino 2016). The figures estimated by Maddison (2010) are 756, 1012, and 1301 USD in 1874, 1890, and 1909, respectively; the recent upward revision is the result of a new estimation of GDP in 1874 (Fukao et al. 2015) and a revision of the backward extrapolation with a more accurate GDP deflator for 1940-1955 (Settsu, Fukao and Bassino 2016).

[6] The share of the labor force in the primary industry (agriculture, fisheries, and forestry) was 71% in 1874 to 62% in 1890, and 58% in 1909. The primary sector accounted for as 50% of GDP in 1874, and still 37% in 1890, 27% in 1909 (Fukao et al. 2015).

[7] Shinohara (1963) presents information on consumption for the main staples in volume and value. Importations of foodstuffs were negligible before 1918.

through spectral analysis. Section 5 models the impact of economic and climatic shocks on human stature. Section 6 brings together our conclusions.

2. Anthropometric data for Japan (1872-1917)

2.1. Dataset

We obtain the official conscription reports of the Japanese army available between 1892 and 1937.[8] In Japan, the entire male cohort was measured at age 20 during the period 1892-1937 without truncation (no minimal height requirement for inclusion of the information in the reports).[9] This source enables us to avoid issues of sample-selection bias that have been identified for instance for 19th century U.S. data (Bodenhorn et al. 2017). Before 1898, regional conscription data are for the traditional administrative units (*kuni*). We convert data from *kuni* to prefectures *(*47 units*)* by comparing administrative maps. In most cases, the prefecture is equivalent to one or two *kuni*. The original data reports the number of conscripts in ten height intervals (including two open lower and upper tails), measured in *shaku* (30.303 cm). We convert the data into centimeters and calculate the median value of each interval. For the upper and lower open tails, we assume that the difference between the median value of the open tail and the median value of the closest interval is equal to the difference between the medians of adjacent intervals.[10] We then rely on those median values and on the number of conscripts reported for each interval of body height to calculate average body height for each year and prefecture. We also estimate height dispersion by calculating the annual coefficient of variation (using the average height calculated for each year and prefecture in the first step).

INSERT FIGURE 1 ABOUT HERE

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[8] Data are missing after 1937, except for 1941. Conscription ended in 1945, i.e. year of birth 1925, but the information is unavailable after 1921.

[9] The original sources are *Rikugunshō Tokei Nenpō* [Statistical Yearbook of the Imperial Army], *Nippon Teikoku Tōkei Nenpō* [Statistical Yearbook of the Empire of Japan] and *Nippon Rikugun Chōhei Tekiyō* [Report on the Conscription of the Japanese Army]. About 98% of the conscripts were in the Army and about 2% in the Navy. As the Navy conscripts originated from all Japanese prefectures, incompleteness of the coverage is unlikely to result in a selection bias.

[10] Because the number of conscripts in the open tails and in the intervals close to these open tails is small, this approximation is unlikely to impact the values of average heights. Furthermore, the percentage of conscript for which the information is reported as missing is extremely low and, for each year and each prefecture, the population of the cohort is normally distributed among the height intervals.

As shown in figure 1, prefecture-level annual height series display a general upward secular trend in stature. However, the figure displays fluctuations that are invisible (or less visible) on national series, indicating that a number of asymmetric shocks might have induced short-term deviation from the trend. The magnitude of those deviations from the trend is particularly large in a number of rural prefectures, such as Okinawa, Nagasaki or Akita. Overall, these fluctuations decreased and faded after the turn of the 20th century, which appears consistent with the gradual process of market integration observed during the late 19th century that resulted in a decline in short term volatility and a convergence of unit-prices of food items towards Tokyo levels[11]. This suggests that the impact of asymmetric shocks related to local climate anomalies (or eventually other change in local conditions) became smaller. Exogenous shocks were still probably affecting agricultural output volume during the interwar, but the lower short-term volatility in the prices of food items suggests that shipment of grain from other regions or from overseas allowed maintaining a relatively stable food supply during the years of crop failure.

2.2. Height and economic conditions

In order to relate short-term variations in income to height cycles, we need to identify the period(s) of life during which the growth of stature is particularly sensitive to economic conditions. The adult height of an individual reflects the combined influences of nutritional status, health conditions, and other environmental variables at different ages, from gestation to early adulthood. However, accelerated growth only during infancy and childhood is one of the main explanatory factors for the secular increase in height (Boyne et al. 1957; Lenz and Ort 1959; Brundtland et al. 1980). In addition, there is increasing observational and experimental evidence also supporting a relation between growth and development during fetal and infant life and health in later years. In particular, growth potential for stature during the period between conception and early adulthood is determined by two key factors: genes, and ‘maternal constraint’ which limits the growth of the foetus *in utero*. Maternal constraint is determined by body size, and increases with the effects of unbalanced maternal diet, excessive maternal thinness, or maternal disease, which influence the delivery of nutrients to growing fetal tissues (Cole, 2003; Gluckman, et.al. 2008). Thus, depending on economic conditions, a certain

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[11] Regional price volatility series are not shown for space-saving consideration but are available from the authors upon request.

percentage of the population will never reach their potential stature. This hypothesis is confirmed by studies showing a clear social stratification in stature: adults from families of better economic circumstances tend to be taller than those from families of lower socio-economic background (Kuh, Power and Rodgers 1991; Gurzkowska et.al. 2014). Thus, if the initial income level is only slightly above subsistence level, as was the case in late 19th and early 20th century Japan - even in higher income prefectures such as Tokyo and Osaka - a sudden decline in disposable income during gestation and infancy could result in a drop in stature for the affected cohort[12].

We thus posit that the mean and the dispersion of height for individuals aged 20 measured in 1892-1937 is impacted by adverse economic shocks affecting living conditions during the year of birth (t-20), the year during which gestation took place (t-21), and the year preceding gestation (t-22) (1870-1917). Unfortunately, data on the distribution of months of birth for each cohort is not available, making it impossible to compare and contrast the importance of each critical year. To address this issue, we define our dependent variable as a rolling moving average of height and height dispersion, respectively, over the three critical years (t-20, t-21, t-22). This smoothing method approach has three advantages in the context of our study: it mitigates the interpretation bias arising from variations in the distribution of birth months in the sample, and sheds lights on deviations from the underlying trend in stature. It also generates more conservative model estimates by decreasing the variance of the dependent variable.

3. The potential impact of climate anomalies

In 19th century Japan, abnormal rainfall and temperatures were key determinants in yearly variations in agricultural output volume. Considering that agricultural output volume data for food-items other than rice are not very reliable before the early 20th century, the best approach for analyzing the relation between height cycles and the asymmetric shocks affecting agricultural output is to rely directly on climate data.

Our climate dataset ranges from 1872 through 2002 and records monthly temperature and rainfall recorded by the Japanese Meteorological Agency and its forerunners. It covers 17 cities, which are prefecture capitals and are shown in figure 2[13]. All of these cities, except Nagano, are

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[12] In a similar vein, Baten, Crayen and Voth (2014) have identified irreversible effects in terms of cognitive skills in the case of the British cohorts born during the Napoleonic blockade, particularly in the regions relying on grain imports.

[13] The 17 weather stations, located in the capital cities of prefecture, are as follows (from north to south; name of the prefecture in parentheses): Sapporo (Hokkaido), Akita (Akita), Niigata (Niigata), Fukushima (Fukushima),

either seaports or close to the coast. Consequently, they tend to have higher average winter temperatures than most other parts of the prefecture that were at higher altitudes. In the summer, the effect of low altitudes on temperature is partially offset by proximity to the sea. Thus, records from these weather stations can be used a proxy for the entire prefecture.

INSERT FIGURE 2 ABOUT HERE

Temperature and rainfall anomalies could be expected to have a major impact on agricultural output in the Japanese archipelago.[14] In particular, crop yields are highly sensitive to low temperatures and vulnerable to drought stress.[15] Rice, almost exclusively cultivated in paddy fields, is the most important crop in Japan. Rice plants are blossoming in late spring or early summer and output is highly sensitive to low temperatures during that period.[16] Although irrigation enables high resilience to drought, by relying on water released by mountainous areas during the period of cultivation, the extension of irrigated perimeters in the last decades of the 19th century resulted in increased in reliance on water from rainfall. An additional propitious effect of rainfall is to mitigate the adverse effect of the low temperature of water obtained from rivers. For most other crops, in the absence of irrigation infrastructures, sufficient rainfall is necessary to avoid reaching the critical potential soil moisture deficit, beyond which yields are significantly affected[17]. By contrast, above average rainfall does not cause much of a problem except when floods occur (in general as a result of a cyclonic event).

Finally, the combination of high temperature and drought gives the most unfavourable outcome for crop production, since higher temperatures – especially in the summer – increase crow water needs through evapotranspiration (Food and Agricultural Organisation, 1986). A certain

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Kanazawa (Ishikawa), Nagano (Nagano), Tokyo (Tokyo), Hamamatsu (Shizuoka), Nagoya (Aichi), Osaka (Osaka), Hiroshima (Hiroshima). Matsuyama (Ehime), Kochi (Kochi), Fukuoka (Fukuoka), Nagasaki (Nagasaki), Kagoshima (Kagoshima), and Naha (Okinawa). Annual data are available for from the following website: http://www.stat.go.jp/english/data/chouki/index.htm. The regional data set available does not allow us to measure accurately the magnitude of cyclonic events.

[14] Kubota, Kosaka, and Xie (2016) analyze the pattern affecting interannual variability using series starting in the late 19th century, with some considerations on rice yields.

[15] Droughts - which occurred in both eastern and western Japan - caused the most severe famines in Japanese history (Saito 2002). This is particularly well documented for the 16th and early 17th centuries. Also note that in most parts of Japan, total annual precipitation is in a range between 1500 and 2500 mm per year and tend to be concentrated in late spring, summer and early autumn. However, high population density regions of coastal western Japan tend to receive much lower annual precipitation levels (in some cases well below 1000 mm on average), particularly in the area of the inner sea (*Setonaikai*) between Honshu and Shikoku islands.

[16] Yoshino (1993) discusses regional variation in rice yields within Japan on the basis of observations covering more that 100 years; Iizumi, Yokozawa and Nishimori (2011) propose an evaluation of climate change impacts of climate change on paddy rice productivity in Japan.

[17] For instance, in the case of soybean seed yield losses of 73–82% per plant were observed in the plants exposed to drought stress during flowering and pod-setting stage (Wei et.al, 2018).

combination of crops characterized 19th and early 20th century Japanese agriculture: staples that were quasi-cash crops (rice, soybeans, and wheat), subsistence crops mostly self-consumed (barley, buckwheat, millet, sweet potatoes, and other roots and tubers), and industrial crops (e.g. mulberry, which was used in sericulture, tea, or tobacco) are affected by evapotranspiration. Therefore, abnormal temperatures and precipitations in our sample - which are purely exogenous[18] and asymmetric shocks - could result in severe crop failures (or exceptional bumper crops) and drastically depress (or strongly increase) agricultural income. In a rural society such as Japan's, failed crops may be expected, in turn, to affect economic conditions and other indicators of well-being such as height, mortality, or birth rates.[19] Hypothesizing a link between regional climatic shocks and economic conditions also appears consistent given the institutional context during the sample period. For instance, the Meiji land tax reform of 1873 (*chisokaisei)* introduced a cash-based taxation system in which taxes were calculated as a proportion of the cash value of the land based on harvest potential, rather than actual crop yield. This, in effect, transferred the risk of crop fluctuation from the government to the farmers[20]. By the end of the Meiji period (1912) about 67% of peasant families were driven into tenancy and half their crops were paid as rent, the rest being used as subsistence or cash crop (Francks, 2004). The economic welfare of the majority of the population thus depended on annual crops, which were, in turn, vulnerable to unpropitious climate conditions.

To capture climate events, we rely on prefecture level monthly rainfall and temperature primary data and construct two separate indices: a monthly abnormal temperature index and an annual drought index. For a given month, the abnormal temperature index is defined as the deviation of the observed temperature from the recorded long run average (in percentage points). It corresponds to the average month value recorded for the corresponding year divided by the average temperature for the same month for the entire period (up to 2002), minus unity. Data is available from 1876 onwards (note that the earliest data point changes per prefecture).

The annual drought index is defined as the expected rainfall expressed a proportion of the observed rainfall. It is calculated as the ratio of the average rainfall for the entire period (up to 2002) to the annual rainfall of the year. Prefecture-level data is available from 1886 onwards.

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[18] It is well documented that rainfall and temperature anomalies occurring in East Asia are mostly related to El Niño-–Southern Oscillation (e.g. Yuan and Yang 2011), although some additional influence of the Solar Cycle can be also identified (Zhou et al. 2013).

[19] For instance, Hall (1985) observed that below normal harvests influenced birth rates in Japan using regional rice output and yields series for 1887-1911.

[20] The tax reform resulted in several farmer insurrections against the Meiji government, including the Ise Revolt (*Ise bōdō*) and the Makabe Revolt (*Makabe bōdō*). The discontent also helped fuel the Freedom and People's Rights Movement (*jiyūminken undō*).

The distribution of the two indices, which is shown in figure 3, reveals positive skewness and kurtosis. This indicates that adverse climate anomalies are present in the sample.

INSERT FIGURE 3 ABOUT HERE

We use the unit-prices of the three main staple crops (rice, barley, and soybeans) - for which prefecture level data are available at the prefecture level from 1874 onwards - to control for fluctuations in agricultural income and other factors that may have influenced the value of crops (such as fiscal and monetary policy shocks, or regional market fluctuations[21]). For instance, the deflationary Matsukata Fiscal Policy from 1881 on severely depressed rice prices, leading to bankruptcies in the farming sector and causing many small landholders to lose their fields to money-lending neighbors (and seek work in the textile mills). These unit-prices also capture the effects of other various unpropitious and unmeasured climate conditions (such as excessive wind, hale, storms, etc…) which could typically occur from October to May for barley (mostly cultivated as secondary winter crop in paddy fields after the rice harvest), and from May to September for rice and soybeans (summer crops cultivated, respectively, in irrigated paddy-fields and in dry fields).

3. Macroeconomic data

Our primary measure of macroeconomic business cycle data is obtained from the growth rate in real per capital GDP in 1990 International Geary-Khamis dollars, which we obtained from the Historical Statistics of the World Economy database (Maddison, 2010) on the basis of the estimates of the Long Term Economic Statistics project (LTES).[22] Using these series allows us to analyse the effects of fluctuations for the national economy as whole.[23] We also use the value of the national production of the manufacturing industry (in 1934-1936 prices) as an alternative indicator. The latter is taken from the LTES series, which are generally regarded as providing

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[21] Underlying data used in Fukao et al. (2015), available from the website of the Institute of Economic Research, Hitotsubashi University.

[22] Ohkawa, K., M. Shinohara, Umemura M., eds, 1965-1983.

[23] As mentioned earlier (note 4), Fukao et al. (2015) proposed a substantial upward of revision in comparison with the LTES GDP estimates for 1874 in current and constant local currency, but not for 1890 and 1909. Their estimates imply a lower compound growth rate of per capita GDP for 1874-1890 that in the LTES series. For 1874, the major source of adjustment was related to agricultural output volume on the basis of prefecture level information. Since Fukao et al. (2015) did not estimate continuous yearly series for 1874-1890, there is no alternative to the LTES series. We take the view that, although the LTES growth rate series tend to overstate the amplitudes of the fluctuations, the years of peak and troughs would not be affected.

fairly dependable estimates for the pre-WWII period[24]. This indicator allows us to take into account the effects of shocks originating in the most modern parts of the Japanese economy.[25] As shown in figure 4, both indicators are positively correlated and increasing steadily over the study period. GDP per capita, however, appears more volatile, which is due to demographic and other macroeconomic changes (such as changes in the trade balance, government spending and production in non-industrial sectors, in particular the primary sector).

INSERT FIGURE 4 ABOUT HERE

We also retrieve prefecture-level GDP for the 3 years for which estimates are available: 1874, 1890, 1909 (Settsu et.al, 2016). Several other national-level economic series are available but do not seem suitable for our purpose. For instance, national-level series of agricultural output value in constant price are available, but these have been estimated using Tokyo prices although regional differences in level and short-term volatility persisted up to the 1890s. In addition, estimates of agricultural output volume for the 1870s and 1880s are based on series recorded by the Ministry of Agricultural and Commerce that tend to underestimate the output volume of staple food items other than rice (such as sweet potatoes, barley, millet, buckwheat, and other miscellaneous cereals) which played a central role in Japanese agriculture up to the early 20th century (Umemura, 1991; Bassino 2006). These series are therefore unlikely to provide a better indicator than per capita income.

Another obvious candidate would be aggregate money supply (or the consumer price index). However, given that about half of Japanese households were still living in rural areas and relied to some extent on self-consumption, macroeconomic monetary shocks were unlikely to have exerted a significant impact on their standard of living. In addition, high levels of short-term volatility and large regional differentials in unit-price of food items imply that shocks originating from changes in monetary policy (or in sudden variation in world prices of species and commodities) did not have the same impact throughout Japan. The same remark applies to variations in the price of food relative to non-food items. Our model thus instead directly

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[24] Data source: Japan Statistical Association (1999), *Historical Statistics of Japan on CD-ROM (1868-1085).* These are the series most commonly used for the identification of business cycles in pre-WWII Japan. Other monetary and real series are also used by Fujino (1965, 1966), Ohkawa and Rosovsky (1962), Shinohara (1963, 1978), and Kuznets (1968): bank deposits, loans, industrial prices, per capita manufacturing output, per capita consumption, and share of consumption in GDP. The dates of peaks and troughs are only slightly affected by the choice of indicator.

[25] The secondary sector accounted for 7.5%, 12%, and 16.5% in 1874, 1890, and 1909, respectively (Fukao et al. 2015).

captures the effects of monetary policy by taking into account changes in the price of cash-crops (at the microeconomic level), and observed reversals in the business cycle (at the macroeconomic level)[26].

Finally, series of gross fixed capital formation (GFCF) are available but underestimate investment in the agricultural sector, and their coverage of the component for residential construction seems limited to Tokyo. GFCF series therefore do not reflect aggregate capital formation per se but rather the combination of public investment (including military equipment) and private investment in mining, manufactures, non-residential construction and transportation. In summary, we focus on the two main determinants of human welfare: the impact of regional-level climate anomalies (affecting local agricultural income as well as the quality of food supply); and the influence of changing macro-economic conditions (which we measure through GDP per capita and the national industrial production index).

4. Business cycles and height cycles

We begin the analysis by detecting potential effects of the business cycle on human stature. The dynamics of both economic and anthropometric variables can indeed be decomposed as a combination of a long-term trend and short terms fluctuations. We use spectral analysis in order to derive a measure for synchronization frequency by frequency, focusing on three standard business cycle frequency intervals: the 7-10 year range ("Juglar" cycle), the 3-5 year range ("Kitchin" cycle), as well as an intermediate 5-7 year range.[27] We then identify the dominant cycle band by calculating the share of total variance attributable to cycles in these intervals. To address the issue of co-movement, we decompose the variance for each frequency band in the height spectrum into a component explained by the business cycle measure and an unexplained component. Finally, we adopt the dynamic correlation measure suggested by Croux, Forni and Reichlin (2001) to distinguish between in-phase and out-of-phase movements. We proceed as follows: first, we filter annual series of height and macroeconomic variables to achieve stationarity. We then fit a vector-autoregressive model (VAR) to the filtered data. Finally, we

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[26] Ideally, we would like to use regional-level information on variations in the relative price of food items in order to investigate the role of these asymmetric shocks. Unfortunately, the information on the price of non-food items is available only for a few prefectures and it does not cover the entire period.

[27] For the sake of convenience, we use these terms when referring to fluctuations with relatively stable periods identified by Juglar (1889) and Kitchin (1923). This does not imply that we need to consider the causal mechanism they propose, or to adhere to the theoretical framework combining business cycles of different periods, including "Kitchin" and "Juglar" cycles proposed by Schumpeter (1939). The assessment of the welfare cost does not require us to distinguish between the various interpretations of the business cycles, in line with the approach pioneered by Lucas (1975, 1987) or by Long and Plosser (1983), for instance.

compute the spectral density matrix of this VAR model, which provides the business cycle measures[28].

There is a body of literature on the consequences of pre-filtering time series before analyzing business cycle stylized facts (Hamilton, 2018). Because our time series are relatively short, we cannot adopt this method, but compare results across filtering methods to establish robustness, as suggested by Canova (1998). Our results are based on height series from the 47 Japanese prefectures in the (measurement) period 1892-1937. Boxplots of the regional distribution of the variance share in the 3-10 years interval are displayed in Figure 3, together with the co-movement measure. The variance share is highest for the HP-filtered series, with a median of about 0.7. As for the difference filter, it is slightly lower, with a median of about 0.6. The in-phase component does not vary a lot across filtering methods.

INSERT FIGURE 3 ABOUT HERE

Results specific to the three business cycle intervals mentioned above (3-5, 5-7, 7-10 years) are displayed in figures 5 to 7. In line with previous studies on business cycles and human stature, we find that the short 3-5 year cycle dominates the height cycle. This result is robust across filtering methods and provides justification for filtering series over the time dimension in the remainder of our empirical framework. Co-movement as measured by the in-phase component of the variance share is slightly higher for the HP-filter than for the difference filter. These preliminary findings thus also clearly indicate correlation between the aggregate business cycle measure and the height cycle.

INSERT FIGURE 5 ABOUT HERE
INSERT FIGURE 6 ABOUT HERE
INSERT FIGURE 7 ABOUT HERE

5. Economic fluctuations and human welfare

5.1. Prefecture level GDP and average height

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[28] A brief description of the method used is provided in the appendix.

We now proceed with an investigation of the impact of the business cycle and climate anomalies on human welfare. We begin by investigating the relationship between prefecture level average height (year of birth) and average GDP for the 3 years of observations for which prefecture level GDP estimates are available: 1874, 1890, and 1909. The results are presented in Table 1 with 4 specifications: log-log and semi-log, OLS and prefecture fixed effects (FE), and in all cases with year dummies. We report significant coefficients for GDP per capita and the time dummies in all four specifications of the estimation, which confirms our previous findings.

INSERT TABLE 1 ABOUT HERE

5.2. Impact of economic and climate shocks on average height

5.2.1. Results from fixed-effect regressions

We then test for the joint impact of macroeconomic fluctuations and regional climate anomalies on average height, using a semi-log specification (Table 2)[29]. We run two sets of estimations, first using GDP per capita and then the national industrial production index as our macroeconomic shock variable. All economic variables are smoothed using a three-year moving average, consistently with the height variables (see the discussion at the end of section 2.2.) and in order to remove the effect of the dominant cycle band identified through spectral analysis. The drought index is also smoothed over the same window in order to take into account the role of mountains as water towers mitigating the risk of crop failure in irrigated perimeters. The abnormal temperature index (which represents a one-period shock) is taken at year t-21.

INSERT TABLE 2 ABOUT HERE

INSERT TABLE 3 ABOUT HERE

Results are shown in table 2 and 3 and can be summarized as follows: average height significantly decreases following drought during gestation and early infancy, and increases both with GDP per capita and the national industrial production index. Not surprisingly, the coefficient observed for GDP per capita, which captures changing conditions in all economic sectors (as well as demographic trends), appears larger than the coefficient observed for the industrial production index.

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[29] The abnormal temperature indices do not need to be log-transformed and are taken in levels.

Abnormally high summer temperatures (especially in August, when paddy is blossoming) also appear to exert a negative and significant effect on average height. This suggests the presence of irremediable welfare costs of climate anomalies and business cycle reversals at low development levels.

We also find that the price of rice exerts a positive and significant coefficient on average height in all specifications. This effect is consistent with the effects of the 1873 tax reform (which in effect transferred crop failure risk from the government to the farmers), and the deflationary Matsukata Fiscal Policy from 1881. The latter severely depressed rice prices, leading to bankruptcies in the farming sector and causing many small landholders to lose their fields to money-lending neighbors (and seek work in the textile mills). By contrast, the coefficients for the prices of both soybeans and barley is never significant, which does not come as a surprise given that these two crops were, to a large extent, self-consumed by the producers as staples[30].

5.2.2. Results from PVAR-X modelling

Climate anomalies may affect height both directly (through a decrease in agricultural income and nutritional status) and indirectly, by destabilizing the level and the distribution of output. We thus now focus on potential systemic interactions between the model's climatic, anthropometric and economic variables variables.

We build a set of PVAR-X models including the significant variables in table 2 and 3 (i.e. the drought index, GDP per capita or the industrial production index and abnormal August temperatures) along with exogenous climate shocks (drought index or abnormal August temperatures). The variance-covariance matrix of the model's canonical innovations is set as symmetrical, and we identify structural shocks by imposing a set of short-run constraints, which involves setting three elements of the transition matrix as equal to zero through a Choleski decomposition.

We rank the model's endogenous variables by expected order of short-term endogeneity. A wide SVAR literature posits that price variables respond to shocks faster than real variables (Kim, 2001; Kim and Roubini, 2000; Sims and Zha, 1995; Kim and Yang, 2008). We thus let orthogonal shocks to the price of rice impact output with a lag. Labor productivity is also widely recognized a determinant of potential output**.** We thus posit that orthogonal shocks to human welfare impact output with a lag (through the impact of the latter on labor productivity, a

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[30] To further establish the impact of climate anomalies on average height, we have also conducted a set of dynamic panel regressions. Results are qualitatively unchanged and shown in the appendix.

determinant of potential output)[31]. Finally, we leave average height (or height dispersion) as the fully endogenous variable in the system[32].

In each model, the business cycle variable (GDP per capita or industrial production) is ranked at the top of the autoregressive vector. Contemporaneous shocks on output are, by way of national accounting, shocks to macroeconomic demand, and are expected to impact prices with a delay. The annual price of rice hence comes second. Average height (or height dispersion) is fully endogenous and comes third. Finally, the two climate anomaly variables (the drought index and the abnormal August temperature index) are added recursively, as purely exogenous shocks.

We thus estimate four separate PVAR-X models, recursively using two endogenous indicators of macroeconomic output and two exogenous indicators of climate anomalies. The models are estimated based on the method described in Abrigo and Love (2015). Two lags are selected, according to the moment model selection criteria of Andrew and Lu (2001). All models respect the eigenvalues stability conditions. Orthogonalized cumulative impulse response functions and the cumulative dynamic multipliers showing the impact of climate anomalies on average height and macroeconomic income are shown in figure 8 and 9[33].

INSERT FIGURE 8a, 8b, 8c ABOUT HERE

INSERT FIGURE 9a, 9b, 9c ABOUT HERE

Figure 8a shows the system of orthogonalized IRF for the PVAR models using Drought as a climate variable, and alternating GDP per capita and the industrial production index as business cycle indicators. In line with the evidence presented in tables 2 and 3, average height responds positively to a structural shock on each macroeconomic output variable, and the observed effect appears stronger for GDP per capita. In addition we find that shocks on average height have a positive lagged impact on GDP per capita and industrial production, which does not come as a surprise in a labour-intensive economy such as 19th century Japan. Finally, structural shocks on the price of rice have a positive impact on average height, which reflects the use of rice as the main cash-crop. Under the Meiji tax system, variations in crop prices also directly impacted the

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[31] Strengthening the population in order to catch up with the West was one objective of Meiji government. In 1872, the Meiji emperor broke a 1,200 year ban on eating the meat of domestic mammals, which was introduced shortly after into the military diet.

[32] Stationarity analysis, PVAR stability results and Granger causality tables are not reported for space-saving consideration but are available upon request.

[33] Following Sims and Zha's (1999) recommendation, we report 68% confidence intervals as these are the most precise estimate of the true coverage probability in the estimation of impulse response functions.

farmers' ability to meet their tax obligations and hence affected nutritional status and average height.

Figure 8b shows that the cumulative response of average height to a (purely exogenous) shock on the drought index is negative. This effect is robust to using the GDP per capita or national industrial production indices. Finally, figure 8c shows that the cumulative response of GDP per capita industrial production to a shock on drought index is negative. Figure 9a, 9b and 9c replicate this analysis, using the abnormal August temperatures index rather than the drought index as a proxy for regional climate anomalies. Results are fully aligned with the findings of figure 8a, 8b and 8c discussed above, and more significant in the case of the impact of climate on the macroeconomic cycle.

Results from the PVAR-X models complement our fixed-effect regression findings by indicating that asymmetric regional climate anomalies not only affected rural income directly, but also exerted systemic effects, by generating unfavourable macroeconomic conditions (measured through GDP per capita and the industrial production index), which deteriorated human welfare. Inspection of the figures also show that macroeconomic indicators responded negatively to deterioration in the human welfare of the population. Our results therefore unambiguously indicate that for low development levels, sizeable climate anomalies could generate a ripple of unfavourable effects on the economic cycle and permanent welfare.

5.3. Impact of economic and climate shocks on height dispersion

5.3.1. Results from fixed-effects regressions

We now test for the impact of macroeconomic fluctuations and climate anomalies on height dispersion (measured as the coefficient of variation across estimated averages of height intervals), using the same model specifications as in the previous section[34]. The results presented in table 4 and 5 indicate that inequalities in stature increase significantly with GDP per capita and the national production index. This can be understood as a consequence of increased income inequality during the early phases of economic growth, where monetary production was driven mostly by the industrial sector, and benefited the households belonging to the upper tail of the income distribution.[35]

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[34] To further establish the impact of climate anomalies on height dispersion, we have also conducted a set of dynamic panel regressions. Results are qualitatively unchanged and shown in the appendix.

[35] The Gini of income inequality that was below 0.40 in 1886 according to Minami (1995a, 1995b), may have been around 35 in around 1860 and at a similar level during the first half of the 19th century (Saito 2008, 258). Japan was a country with a Gini at some distance of the *inequality possibility frontier* as defined by (Milanovic, Lindert and Williamson 2011). Income inequality increased steadily in the late 19th and early 20th century, and reached a peak in the 1930s (Moriguchi and Saez 2008).

In all specification, we find that height dispersion significantly decreases with the price of rice. This result is consistent with the findings obtained with the average height models, and confirms that decreases in the price of rice (e.g. due to the 1881 Matsukata deflationary fiscal policy) triggered a negative income effect for agricultural producers – especially tenants, who represented the majority of farmers and belonged in the lower tail of the income distribution.

Finally, in all specifications, height dispersion increases with drought episodes and August heatwaves. This is understandable as a negative income shock affecting the lower tail of the income distribution (and potentially reinforced by the pro-cyclical effect of the Meiji fiscal system).

To sum up, our findings indicate that climate and economic shocks not only reduced permanent welfare at low development levels, but also increased permanent inequalities in human welfare. As in present-day developing economies, this reflects the high exposure of agricultural producers – who accounted for the largest share of the lower-income households – to interconnected asymmetric climatic and symmetrical macro-economic shocks[36].

INSERT TABLE 4 ABOUT HERE

INSERT TABLE 5 ABOUT HERE

5.3.2. Results from PVAR-X modelling

We then replicate the PVAR-X analysis conducted in section 5.2, substituting height dispersion for average height as the model's fully endogenous variable. The models respect the eigenvalues stability conditions. Orthogonalized cumulative impulse response functions and the cumulative dynamic multipliers of interest are shown in figures 10 and 11.

Figure 10a, 10b and 10c show the system of orthogonalized IRF for the PVAR-X models using the drought index as a climate anomaly variable and alternating GDP per capita and the industrial production index as business cycle indicators. Height dispersion appears to respond negatively to a structural shock on the price of rice, while a structural shock on the drought index significantly increases height dispersion. These findings confirm our previous results. The cumulative dynamic multipliers also show that drought had negative effects on the business cycle. Given the negative response of height dispersion to a structural shock on GDP per capita

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[36] This finding echoes results obtained by Hoddinott & Kinsey (2002) using data for rural Zimbabwe showing that losses in growth resulting from drought are sizeable and unequally distributed among children from poorer households.

and the industrial production index, our interpretation is that climate-induced business cycle reversals were felt by individuals on the lower tail of the distribution (such as tenant farmers), which magnified existing permanent inequalities in welfare.

Figure 11a, 11b and11c replicate this analysis, using the abnormal August temperature index rather than the drought index as a proxy for regional climate anomalies. Results are fully aligned with the findings of figure 10a, 10b and 10c. Overall, the PVAR-X analysis therefore confirms the findings of the fixed effect regression framework and also suggests the presence of systemic effects. Asymmetric exogenous climate shocks not only increased inequalities by depressing rural income, but also triggered a macroeconomic business cycle reversal, which was felt more strongly by the poor, with irremediable consequences for the distribution of human welfare.

INSERT FIGURE 10a, 10b, 10c ABOUT HERE
INSERT FIGURE 11a, 11b, 11c ABOUT HERE

5.4. Simulating the impact on permanent welfare

We finally run a set of simulations using the main regressions in order to shed light on the magnitude of the effects of extreme adverse shocks on human welfare. We first retrieve the most extreme values of the sample: a decline in three-year average per capita GDP of about 8.9% (observed in 1919; the most severe decline in the sample), a decline of the three-year average industrial production index of 6.8% (observed in 1920), a logarithmic value of the three-year average drought index of 0.328 (observed in Fukuoka in 1913, 1914 and 1915 where recorded precipitations for the three year average were 27.9% lower than the long run average) and an August Temperatures index of 0.127 (observed in Hokkaido in 1900 where recorded temperatures were 12.7% higher than the long run average).

INSERT TABLE 6 ABOUT HERE

We use the estimates presented in table 2 and 3 and focus on the tenth column, which gathers the main variables of interest: GDP per capita, drought effects, and abnormal August temperatures. As shown in table 6, we find that the combination of economic and climatic shocks triggers a negative deviation of average stature from its trend of about 2.9 cm (from 1359 mm to 1330 mm), of which 2 mm are due to the business cycle reversal, 11mm are attributed to the drought and 16 mm to the August heat wave. Using the national industrial production index, we find that the combination of economic and climatic shocks results in a negative deviation from the trend of about 0.9 cm (from 1369mm to 1360mm), of which 1mm are due to the business cycle reversal, 3 mm are attributed to the drought and 5 mm to the August heat wave.

Interestingly, the magnitude of these estimates appears in line with previous studies on the impact of economic conditions on secular trends in stature growth. For instance, in the case of Britain, young adult men and women born between the turn of the century (about 1900) and 1958 classified as better-off (non-manual working class background) were, on average, consistently taller by about 2.0 cm and 1.6 cm, respectively that the population classified as unskilled (manual working class background) (Kuh et.al, 1991). These simulations thus back up our results and indicate that climate anomalies exert a permanent impact on human welfare at the low development level.

One noteworthy observation is that even though the reported regression coefficients for the climate anomalies are lower than those of economic shocks (-0.582 for the drought index and -2.302 for the August heatwave index versus 5.559 for the GDP per capita estimations) the simulated impact of climate anomalies on height turns out to be significantly larger than the impact of business cycle reversals. The permanent welfare effects of climate anomalies identified in our study are thus primarily driven by the size of the shocks. This remark appears particularly relevant given the current context of climate change. Environmental scientists have indeed estimated that the likely rate of change over the next century will be at least 10 times quicker than any climate shift in the past 65 million years (Diffenbaugh and Field, 2013). While the relation between climate shocks and the economy is likely to be non-ergodic and context-specific, we have good reasons to believe that our results represent, other things equal, a lower bound for the permanent welfare effects of climate change in developing countries in the 21st century. Given the importance of the agricultural sector, which accounted for a sizable share of GDP[37], the lower coefficient observed for industrial production also indicates that voluntarist and pre-emptive climate change adaptation strategies seeking to change the composition of national production may significantly mitigate the permanent impact of climate anomalies.

6. Conclusion

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[37] 49%, 28%, and 27% in 1874, 1890, and 1909, respectively (Fukao et al. 2015).

The objective of this paper was to contribute to our understanding of the effects of climate anomalies on permanent welfare at low levels of economic development. Taking late 19th and early 20th Japan as a case study, we relied on a unique hand-collected, historical data set including prefecture level and national economic statistics, anthropometric data, and climate records.

We then measured the effect of symmetric (nationwide economic conditions) and asymmetric shocks (regional climate anomalies) during infancy on average height at adulthood using spectral analysis, fixed effect regressions, and the inspection of cumulative impulse response functions and dynamic multipliers from a set of PVAR-X models. Our estimations consistently detected that climate anomalies during gestation and early infancy induced a decrease in average height observed at adulthood, as well as an increase in height dispersion, indicating greater welfare inequalities.

The findings presented in the paper have important implications for a large part of the global population. The Japanese situation demonstrates that in a country with relatively sound institutions in place, average per capita income above subsistence level[38], relatively low levels of inequality, a high degree of market integration, a steady upward trend for all indicators of human development and monetary income, benefiting from relatively abundant rainfall, and with a relatively efficient infrastructure of irrigation networks, short-term climate anomalies still have a strong and irreversible impact on welfare for most of the population, particularly the lower deciles of the population. Our results therefore confirm that ongoing climate change is a disruptive force affecting economies and societies especially the poorest segments of the population in lower income countries. Rising to this challenge will require a prompt international effort towards the diffusion of practices aimed at tackling poverty and strengthening shock resilience.

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[38] Japanese per capita GDP was close to 3 dollars a day in 1874 (measured in dollars of 1990).

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TABLES AND FIGURES

Table 1. Estimation results for prefecture level average height in mm (log-log and semi-log)

	(1) log-log	(2) log-log	(3) semi-log	(4) semi-log
lnGDP per capita	0.007 (3.90)***	0.054 (2.14)***	11.38 (3.92)***	8.43 (2.13)**
Year 1874	-0.020 (-16.66)***	-0.021 (-23.73)***	-31.53 (-16.70)***	-32.90 (-23.85)***
Year 1890	-0.010 (-8.72)***	-0.010 (-14.09)***	-15.87 (-8.79)***	-16.36 (-14.25)***
Intercept	7.32 (554.02)***	7.33 (411.69)***	1515 (72.74)***	1527 (52.53)***
Adj. R2	0.74	0.92	0.74	0.92
Observations	140	140	140	140
Specification	OLS	Prefecture FE	OLS	Prefecture FE

Sources: Conscription records for average height (in mm) measured in 1894, 1910, and 1929 (conscripts born in 1874, 1890, and 1909, respectively); Settsu et al. (2016) for per capita GDP (in 1990 USD) in 1874, 1890, and 1909.

Note: 47 prefectures; height data missing in 1874 (year of measurement) for Okinawa.

Table 2 Height models: estimation results with climate data and prefecture fixed effect regressions (GDP per capita)

Drought	-0.716***	-0.745***	-0.715***	-0.718***	-0.722***	-0.744***	-0.719***	-0.653***	-0.747***	-0.582***	-0.725***	-0.714***	-0.739***	-0.715***
	(-4.130)	(-4.228)	(-4.121)	(-4.136)	(-4.167)	(-4.293)	(-4.184)	(-3.857)	(-4.255)	(-3.428)	(-4.188)	(-4.087)	(-4.249)	(-4.117)
GDP per capita	5.309***	5.328***	5.297***	5.313***	5.330***	5.364***	5.301***	5.838***	5.237***	5.559***	5.422***	5.270***	5.479***	5.305***
	(20.44)	(20.45)	(20.36)	(20.44)	(20.51)	(20.61)	(20.59)	(21.46)	(19.58)	(21.72)	(20.36)	(19.25)	(20.32)	(20.35)
Interaction		-1.369												
		(-1.144)												
Soy price	-0.0724	-0.0902	-0.0727	-0.0768	-0.0652	-0.0757	-0.0468	-0.0916	-0.0797	-0.0921	-0.116	-0.0691	-0.102	-0.0725
	(-0.587)	(-0.725)	(-0.589)	(-0.622)	(-0.528)	(-0.616)	(-0.382)	(-0.763)	(-0.646)	(-0.770)	(-0.924)	(-0.557)	(-0.822)	(-0.587)
Rice price	0.293**	0.303**	0.296**	0.295**	0.283**	0.291**	0.289**	0.0982	0.343**	0.191	0.266**	0.302**	0.261**	0.295**
	(2.280)	(2.350)	(2.297)	(2.296)	(2.196)	(2.273)	(2.270)	(0.753)	(2.521)	(1.512)	(2.063)	(2.318)	(2.027)	(2.286)
Barley price	0.0797	0.0727	0.0790	0.0757	0.0769	0.0700	0.0631	0.135	0.0657	0.0813	0.0888	0.0825	0.0668	0.0795
	(0.897)	(0.816)	(0.889)	(0.851)	(0.867)	(0.790)	(0.716)	(1.547)	(0.733)	(0.944)	(1.001)	(0.925)	(0.753)	(0.895)
January			0.0212											
			(0.875)											
February				0.0229										
				(0.839)										
March					0.0608									
					(1.470)									
April						0.356**								
						(2.050)								
May							-0.930***							
							(-3.045)							
June								-1.546***						
								(-5.239)						
July									0.400					
									(1.115)					
August										-2.302***				
										(-5.528)				
September											-0.556*			
											(-1.846)			
October												0.132		
												(0.455)		
November													-0.214**	
													(-2.269)	
December														0.00722
														(0.212)
Constant	120.7***	120.6***	120.8***	120.7***	120.6***	120.3***	120.7***	117.4***	121.1***	119.2***	120.0***	120.9***	119.6***	120.7***
	(74.55)	(74.28)	(74.47)	(74.50)	(74.44)	(74.13)	(75.23)	(69.16)	(72.84)	(74.85)	(72.57)	(70.89)	(71.29)	(74.32)
Observations	485	484	485	485	485	485	485	485	485	485	485	484	484	485
Number of prefecture	17	17	17	17	17	17	17	17	17	17	17	17	17	17
R-squared overall	0.335	0.338	0.866	0.866	0.867	0.867	0.869	0.874	0.334	0.346	0.867	0.335	0.867	0.335
R-squared between	0.172	0.164	0.171	0.170	0.169	0.166	0.166	0.153	0.174	0.154	0.163	0.167	0.158	0.172
R-squared within	0.866	0.866	0.866	0.866	0.867	0.867	0.869	0.874	0.866	0.874	0.867	0.866	0.867	0.866
F test	598.4	496.9	498.6	498.5	500.3	502.8	509.1	531.7	499.1	535.6	501.8	495.5	501.7	497.7

Note: t statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Drought, production indices as well as soy, rice and barley prices are taken in logarithm and smoothed over t-20, t-21, t-22 time periods corresponding to first year of life, year during which gestation took place, and conditions to which the mother was exposed the year preceding the gestation period. Interaction corresponds to the product of the regional drought index (taken in deviation from the full sample mean) and the national industrial production index (purged from the effects from regional drought, temperature anomalies and variations in the price of rice, soy and barley). Monthly temperatures are taken as deviation from the full sample average and observed at t-21.

Table 3 Height models: estimation results with climate data and prefecture fixed effect regressions (national industrial production index)

Drought	-0.706***	-0.736***	-0.704***	-0.706***	-0.713***	-0.730***	-0.709***	-0.636***	-0.698***	-0.569***	-0.719***	-0.705***	-0.736***	-0.702***
	(-3.979)	(-4.084)	(-3.971)	(-3.977)	(-4.028)	(-4.115)	(-4.029)	(-3.691)	(-3.882)	(-3.276)	(-4.080)	(-3.948)	(-4.155)	(-3.952)
Production	1.694***	1.701***	1.690***	1.694***	1.705***	1.709***	1.691***	1.900***	1.702***	1.782***	1.760***	1.689***	1.777***	1.691***
	(19.48)	(19.49)	(19.42)	(19.46)	(19.60)	(19.60)	(19.60)	(20.69)	(18.56)	(20.76)	(19.58)	(18.28)	(19.51)	(19.42)
Interaction		-1.419												
		(-1.160)												
Soy price	0.100	0.0825	0.0994	0.0994	0.109	0.0996	0.126	0.0893	0.102	0.0858	0.0355	0.102	0.0640	0.0988
	(0.814)	(0.662)	(0.805)	(0.804)	(0.883)	(0.808)	(1.025)	(0.747)	(0.825)	(0.716)	(0.284)	(0.819)	(0.519)	(0.800)
Rice price_	0.499***	0.509***	0.501***	0.500***	0.485***	0.499***	0.495***	0.294**	0.485***	0.400***	0.458***	0.502***	0.459***	0.503***
	(3.905)	(3.976)	(3.920)	(3.908)	(3.799)	(3.921)	(3.908)	(2.279)	(3.549)	(3.199)	(3.581)	(3.879)	(3.596)	(3.935)
Barley price	0.0620	0.0546	0.0612	0.0606	0.0588	0.0531	0.0456	0.123	0.0656	0.0634	0.0763	0.0629	0.0454	0.0617
	(0.683)	(0.600)	(0.675)	(0.666)	(0.649)	(0.586)	(0.506)	(1.387)	(0.715)	(0.721)	(0.845)	(0.690)	(0.503)	(0.680)
January			0.0259											
			(1.045)											
February				0.00740										
				(0.265)										
March					0.0740*									
					(1.749)									
April						0.315*								
						(1.777)								
May							-0.919***							
							(-2.943)							
June								-1.713***						
								(-5.628)						
July									-0.102					
									(-0.271)					
August										-2.347***				
										(-5.500)				
September											-0.830***			
											(-2.671)			
October												0.0475		
												(0.158)		
November													-0.281***	
													(-2.886)	
December														0.0263
														(0.757)
Constant	132.6***	132.6***	132.7***	132.6***	132.5***	132.4***	132.7***	130.0***	132.5***	131.6***	131.9***	132.7***	131.6***	132.7***
	(122.0)	(121.6)	(121.9)	(121.8)	(121.8)	(121.4)	(123.0)	(113.1)	(116.3)	(122.9)	(118.0)	(114.9)	(115.8)	(121.8)
Observations	485	484	485	485	485	485	485	485	485	485	485	484	484	485
Prefectures	17	17	17	17	17	17	17	17	17	17	17	17	17	17
R2 overall	0.319	0.322	0.860	0.860	0.861	0.321	0.321	0.328	0.320	0.869	0.325	0.860	0.324	0.320
R2 between	0.207	0.200	0.206	0.207	0.204	0.203	0.202	0.193	0.206	0.195	0.197	0.200	0.194	0.207
R2 within	0.860	0.860	0.860	0.860	0.861	0.861	0.862	0.869	0.860	0.869	0.862	0.860	0.862	0.860
F test	568.4	472	473.9	472.7	476.3	476.4	482.9	510.3	472.7	508.6	481.1	470.5	480.3	473.3

Note: t statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Drought, production indices as well as soy, rice and barley prices are taken in logarithm and smoothed over t-20, t-21, t-22 time periods corresponding to first year of life, year during which gestation took place, and conditions to which the mother was exposed the year preceding the gestation period. Interaction corresponds to the product of the regional drought index (taken in deviation from the full sample mean) and the national industrial production index (purged from the effects from regional drought, temperature anomalies and variations in the price of rice, soy and barley). Monthly temperatures are taken as deviation from the full sample average and observed at t-21.

Table 4 Height dispersion models: estimation results with climate data and prefecture fixed effect regressions (GDP per capita)

Drought	0.00101**	0.00101**	0.00100**	0.00100**	0.00101**	0.00103**	0.00101**	0.000901**	0.000928**	0.000863**	0.00102**	0.00102**	0.00106**	0.00102**
	(2.387)	(2.367)	(2.378)	(2.379)	(2.384)	(2.440)	(2.390)	(2.160)	(2.177)	(2.037)	(2.436)	(2.403)	(2.526)	(2.417)
GDP per capita	0.00133**	0.00131**	0.00136**	0.00134**	0.00133**	0.00128**	0.00133**	0.000465	0.00115*	0.00106*	0.00108*	0.000987	0.000810	0.00129**
	(2.105)	(2.071)	(2.155)	(2.119)	(2.100)	(2.012)	(2.110)	(0.693)	(1.767)	(1.663)	(1.667)	(1.489)	(1.242)	(2.034)
Interaction		0.000897												
		(0.309)												
Soy price	9.70e-05	0.000111	9.78e-05	8.71e-05	9.72e-05	0.000100	8.31e-05	0.000128	7.86e-05	0.000118	0.000193	0.000129	0.000188	9.54e-05
	(0.324)	(0.367)	(0.327)	(0.290)	(0.324)	(0.334)	(0.277)	(0.433)	(0.262)	(0.396)	(0.633)	(0.431)	(0.627)	(0.319)
Rice price	-0.00182***	-0.00183***	-0.00183***	-0.00182***	-0.00182***	-0.00182***	-0.00182***	-0.00150***	-0.00170***	-0.00171***	-0.00176***	-0.00174***	-0.00172***	-0.00180***
	(-5.831)	(-5.822)	(-5.852)	(-5.811)	(-5.816)	(-5.823)	(-5.820)	(-4.667)	(-5.127)	(-5.448)	(-5.615)	(-5.514)	(-5.523)	(-5.760)
Barley price	0.000232	0.000235	0.000234	0.000223	0.000232	0.000241	0.000241	0.000143	0.000197	0.000230	0.000212	0.000255	0.000269	0.000231
	(1.077)	(1.084)	(1.086)	(1.034)	(1.075)	(1.116)	(1.116)	(0.664)	(0.907)	(1.074)	(0.984)	(1.181)	(1.253)	(1.070)
January			-6.17e-05											
			(-1.048)											
February				5.14e-05										
				(0.775)										
March					1.56e-06									
					(0.0155)									
April						-0.000328								
						(-0.777)								
May							0.000506							
							(0.676)							
June								0.00252***						
								(3.464)						
July									0.00100					
									(1.151)					
August										0.00245**				
										(2.364)				
September											0.00123*			
											(1.676)			
October												0.00116		
												(1.645)		
November													0.000645***	
													(2.826)	
December														7.94e-05
														(0.962)
Constant	0.0312***	0.0313***	0.0310***	0.0312***	0.0312***	0.0316***	0.0312***	0.0367***	0.0323***	0.0328***	0.0327***	0.0334***	0.0344***	0.0315***
	(7.951)	(7.943)	(7.883)	(7.934)	(7.928)	(7.984)	(7.940)	(8.756)	(8.006)	(8.274)	(8.140)	(8.079)	(8.474)	(7.996)
Observations	485	484	485	485	485	485	485	485	485	485	485	484	484	485
Number of prefecture	17	17	17	17	17	17	17	17	17	17	17	17	17	17
R-squared overall	0.0368	0.242	0.245	0.245	0.244	0.245	0.0372	0.263	0.0400	0.0448	0.248	0.0419	0.0441	0.0375
R-squared between	0.175	0.169	0.175	0.176	0.175	0.171	0.175	0.160	0.174	0.166	0.154	0.161	0.164	0.173
R-squared within	0.244	0.242	0.245	0.245	0.244	0.245	0.244	0.263	0.246	0.253	0.248	0.247	0.255	0.245
F test	29.82	24.57	25.04	24.93	24.80	24.93	24.90	27.44	25.09	26.03	25.42	25.14	26.30	25

Note: t statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Drought, production indices as well as soy, rice and barley prices are taken in logarithm and smoothed over t-20, t-21, t-22 time periods corresponding to first year of life, year during which gestation took place, and conditions to which the mother was exposed the year preceding the gestation period. Interaction corresponds to the product of the regional drought index (taken in deviation from the full sample mean) and the national industrial production index (purged from the effects from regional drought, temperature anomalies and variations in the price of rice, soy and barley). Monthly temperatures are taken as deviation from the full sample average and observed at t-21.

Table 5 Height dispersion models: estimation results with climate data and prefecture fixed effect regressions (national industrial production index)

Drought	0.0009**	0.0009**	0.0009**	0.0009**	0.0009**	0.0009**	0.0009**	0.0009**	0.0009**	0.0008**	0.0009**	0.0009**	0.0009**	0.0009**
	(2.311)	(2.265)	(2.302)	(2.305)	(2.302)	(2.342)	(2.314)	(2.164)	(2.288)	(2.039)	(2.328)	(2.291)	(2.382)	(2.338)
Production	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***	0.0009***	0.001***	0.001***	0.001***	0.001***	0.0009***	0.001***
	(5.468)	(5.433)	(5.516)	(5.459)	(5.469)	(5.391)	(5.474)	(4.207)	(5.202)	(5.055)	(5.062)	(4.983)	(4.640)	(5.425)
Interaction		0.0002												
		(0.0870)												
Soy price	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0001	-0.0002	-0.0002	-0.0002	-0.0002	-0.0001	-0.0002	-0.0001	-0.0002
	(-0.594)	(-0.571)	(-0.584)	(-0.617)	(-0.582)	(-0.592)	(-0.644)	(-0.562)	(-0.591)	(-0.556)	(-0.450)	(-0.562)	(-0.408)	(-0.611)
Rice price	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***	-0.002***
	(-7.337)	(-7.305)	(-7.357)	(-7.306)	(-7.334)	(-7.333)	(-7.326)	(-6.481)	(-6.868)	(-7.024)	(-7.198)	(-7.174)	(-7.111)	(-7.284)
Barley price	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
	(1.402)	(1.394)	(1.412)	(1.359)	(1.394)	(1.426)	(1.444)	(1.145)	(1.393)	(1.400)	(1.358)	(1.422)	(1.502)	(1.398)
January			-6.86e-05											
			(-1.197)											
February				4.59e-05										
				(0.711)										
March					2.88e-05									
					(0.293)									
April						-0.0002								
						(-0.502)								
May							0.0005							
							(0.738)							
June								0.0015**						
								(2.060)						
July									-4.64e-05					
									(-0.0535)					
August										0.002*				
										(1.779)				
September											0.0005			
											(0.681)			
October												0.0003		
												(0.487)		
November													0.0004*	
													(1.732)	
December														7.27e-05
														(0.907)
Constant	0.0258***	0.0259***	0.0257***	0.0259***	0.0258***	0.0260***	0.0258***	0.0281***	0.0258***	0.0266***	0.0263***	0.0263***	0.0273***	0.0259***
	(10.27)	(10.24)	(10.21)	(10.28)	(10.21)	(10.26)	(10.26)	(10.27)	(9.784)	(10.45)	(10.10)	(9.841)	(10.32)	(10.30)
Observations	485	484	485	485	485	485	485	485	485	485	485	484	484	485
Prefecture prefecture	17	17	17	17	17	17	17	17	17	17	17	17	17	17
R 2overall	0.035	0.035	0.036	0.035	0.035	0.036	0.284	0.041	0.035	0.040	0.038	0.282	0.286	0.284
R2 between	0.214	0.211	0.214	0.214	0.215	0.213	0.214	0.211	0.214	0.211	0.208	0.210	0.210	0.213
R2 within	0.283	0.281	0.285	0.283	0.283	0.283	0.284	0.289	0.283	0.288	0.283	0.282	0.286	0.284
F test	36.49	30.07	30.68	30.46	30.36	30.40	30.47	31.33	30.34	31.08	30.45	30.12	30.76	30.53

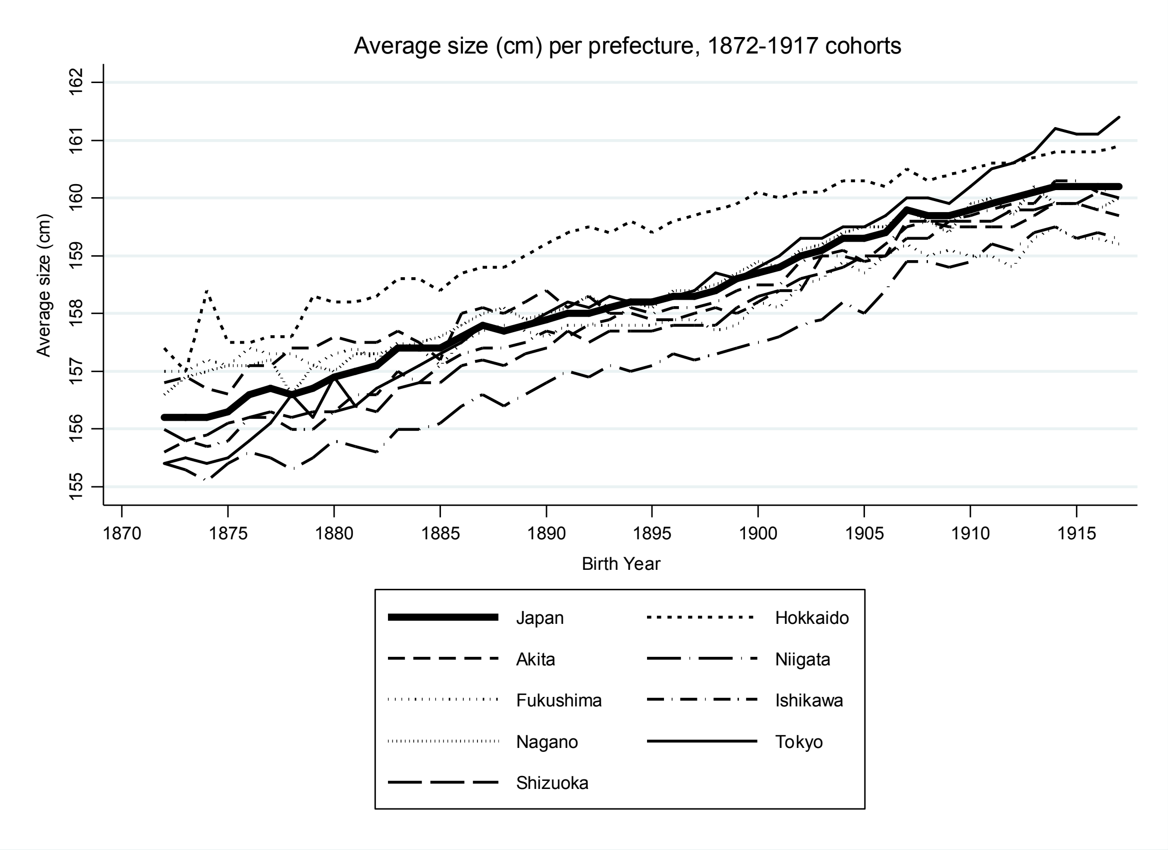
Note: t statistics in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.10$. Drought, production indices as well as soy, rice and barley prices are taken in logarithm and smoothed over t-20, t-21, t-22 time periods corresponding to first year of life, year during which gestation took place, and conditions to which the mother was exposed the year preceding the gestation period. Interaction corresponds to the product of the regional drought index (taken in deviation from the full sample mean) and the national industrial production index (purged from the effects from regional drought, temperature anomalies and variations in the price of rice, soy and barley). Monthly temperatures are taken as deviation from the full sample average and observed at t-21.

Table 6 Model simulation

Simulated model	Table 2, Column 10	Table 3, Column 10
Predicted height : baseline scenario (mm)	1359	1369
Predicted height : economic and climatic shocks (mm)	1330	1360
Decomposition of observed gap:		
Recession	2	1
Drought	11	3
Heat wave	16	5

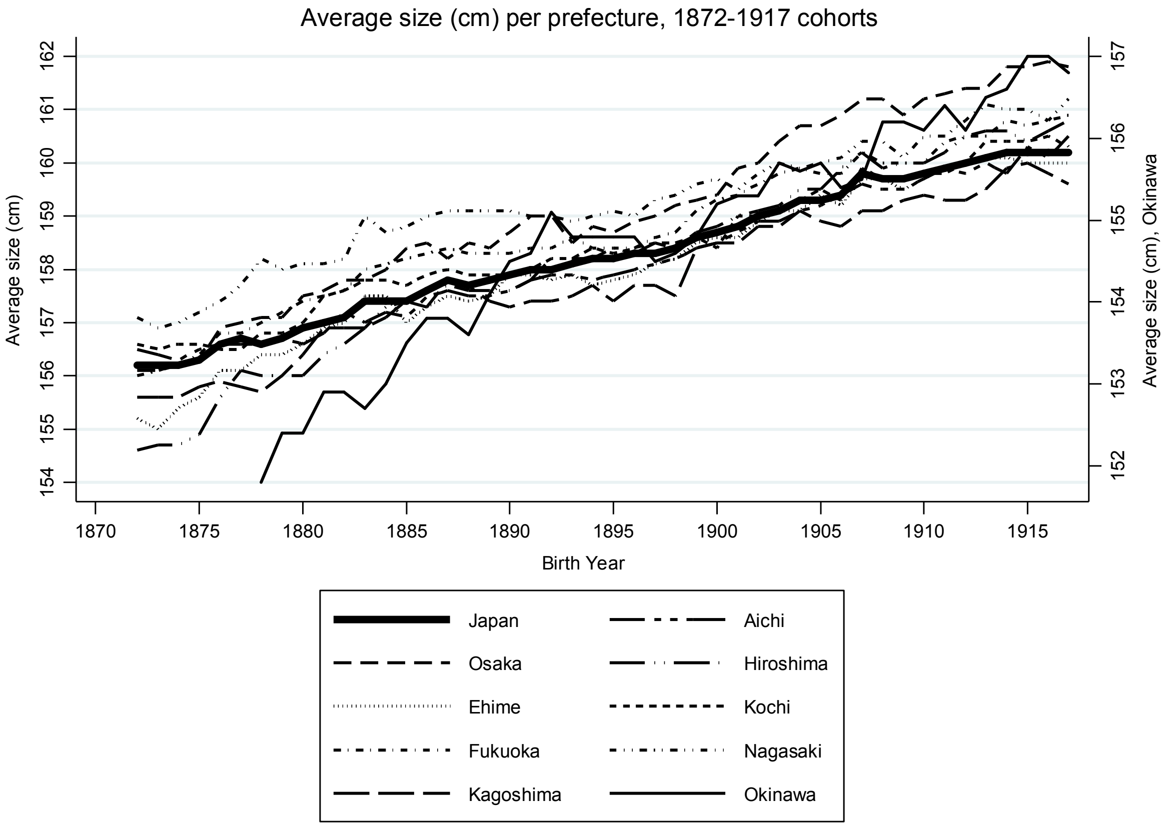
Note: this table report the result of simulations based on the fixed-effect models presented in table 2 and 3.

Figure 1a. Average height in cm of Japanese conscripts measured at age 20 (date of birth) in Hokkaido, Akita, Niigata, Fukushima, Ishikawa, Nagano, Tokyo, Shizuoka prefectures, and for Japan as a whole.



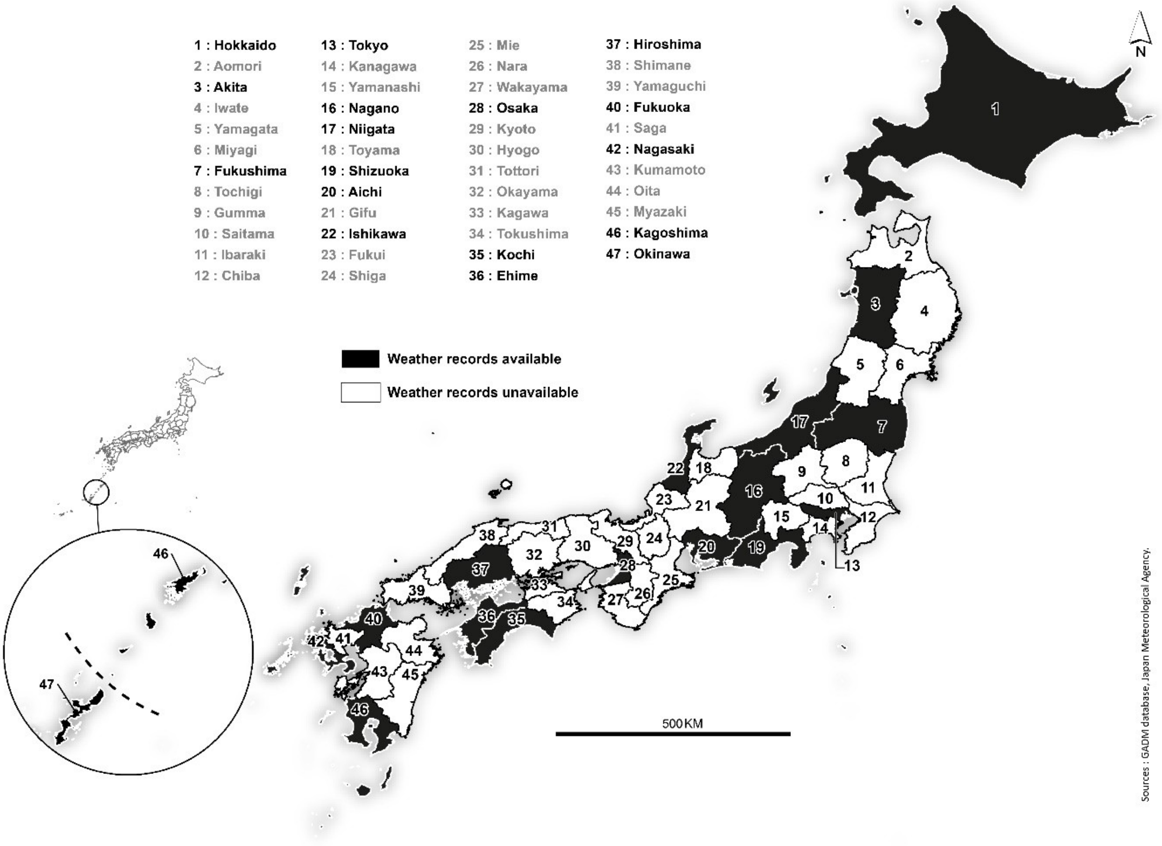
Sources: conscription records.

Figure 1b. Average height in cm of Japanese conscripts measured at age 20 (date of birth) Aichi, Osaka, Hiroshima, Ehime, Kochi, Fukuoka, Nagasaki, Kagoshima, and Okinawa prefectures, and for Japan as a whole.



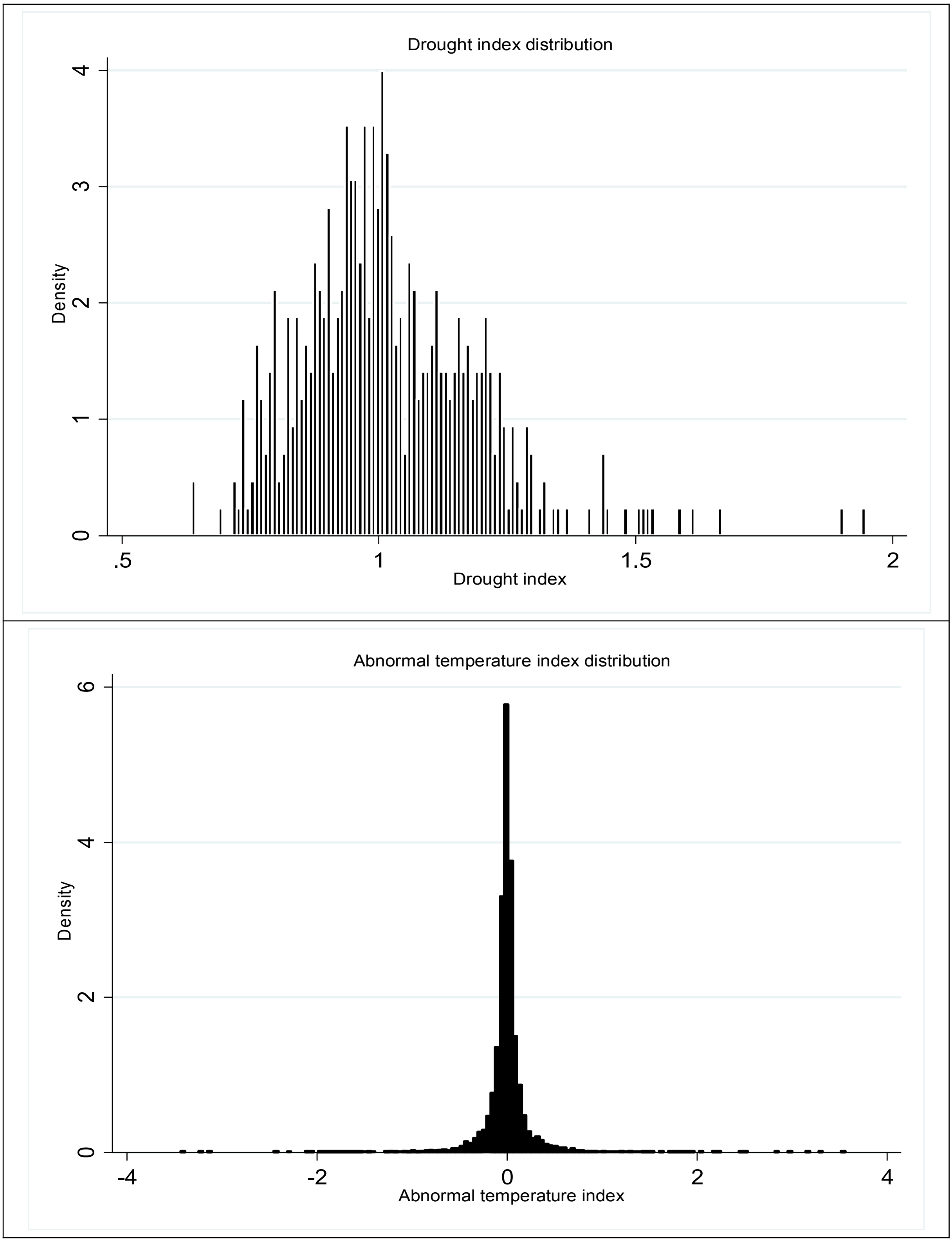
Source: conscription records.
Note: Y-axis for Okinawa prefecture is reported on the right-hand scale.

Figure 2: Prefectures with available climate data



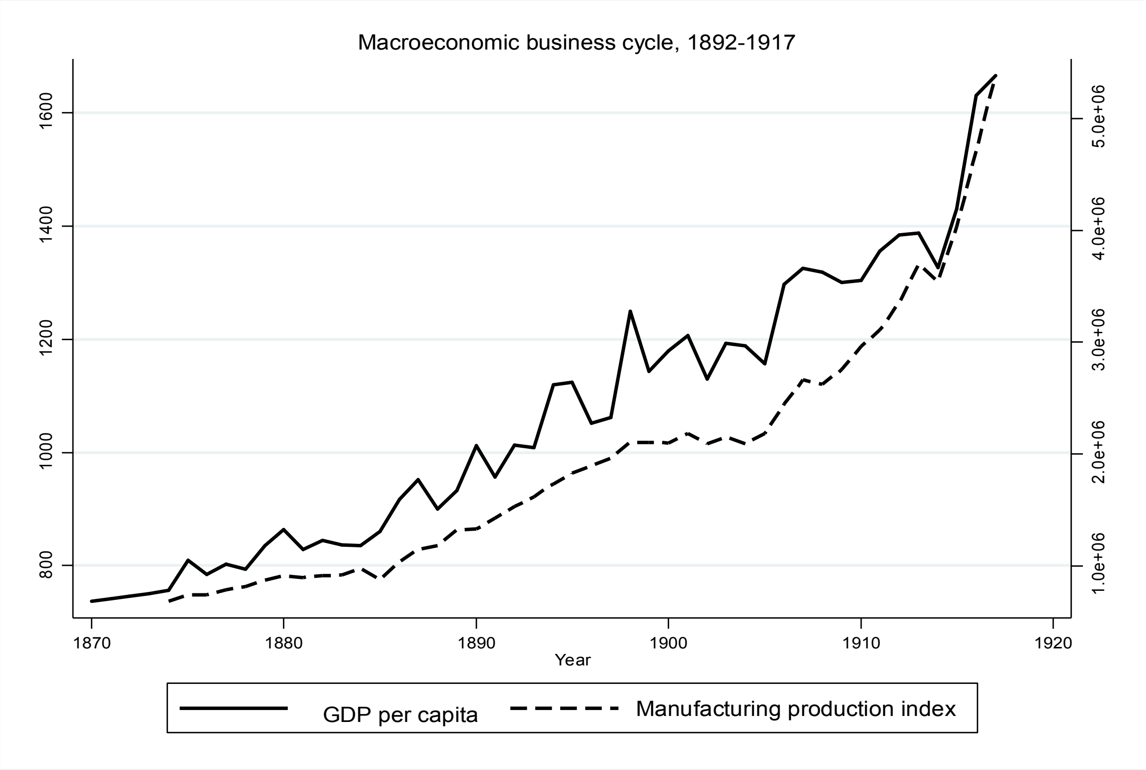
Sources : GADM database, Japan Meteorological Agency.

Figure 3 Climate data: histograms



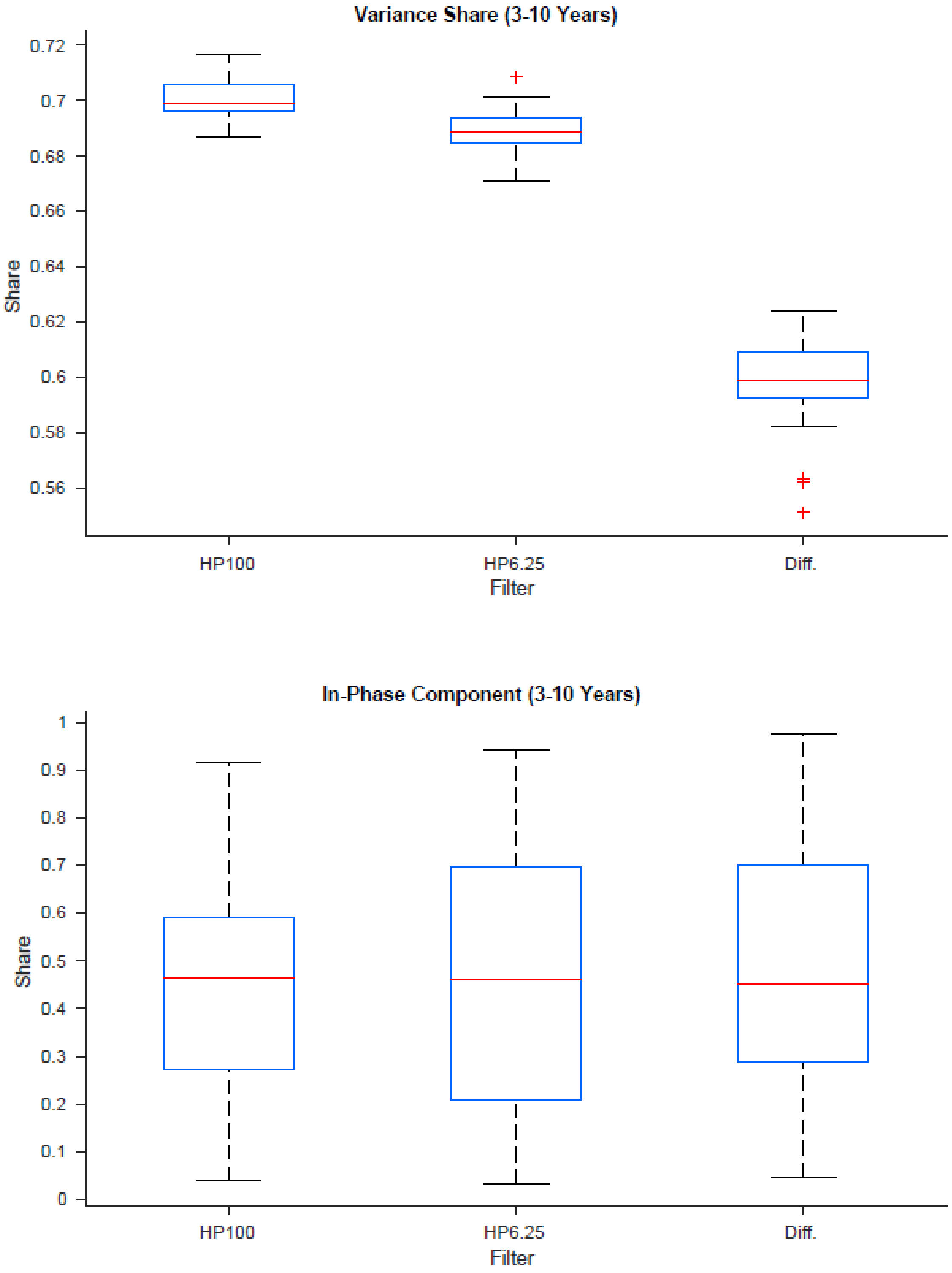
Note: the upper figure shows the density histogram of the drought index. The lower figure shows the density histogram of the abnormal temperature index. The drought index has positive skewness (1.10) and kurtosis (6.10). The abnormal temperature index has positive skewness (0.46) and kurtosis (39.14).

Figure 4 Macroeconomic business cycle



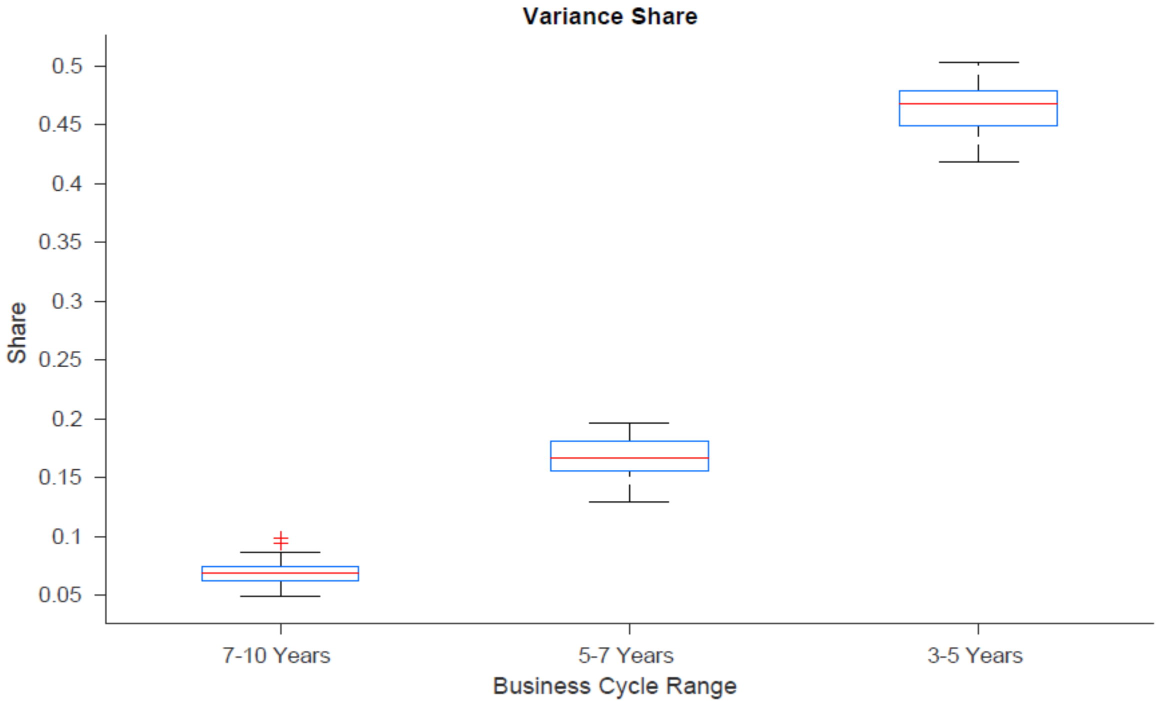
Note: Real per capita GDP is measured on the left-hand scale (in 1990 International Geary-Khamis dollars). The industrial manufacture production index is measured on the right-hand scale (in 1934-1936 prices).

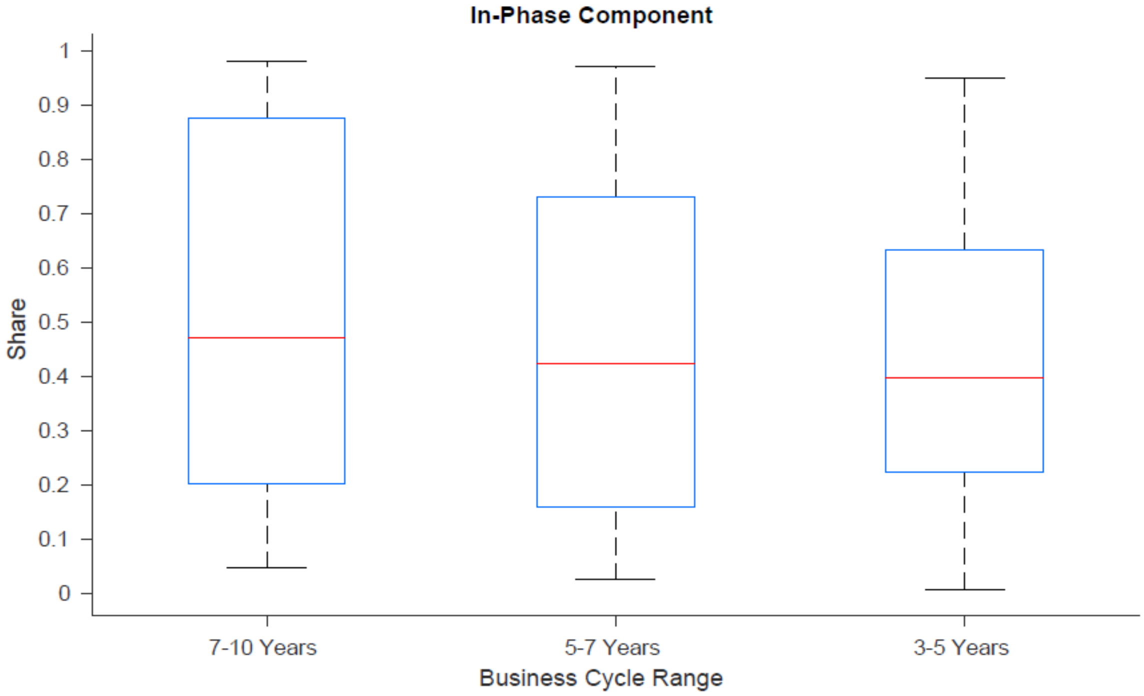
Figure 5: Variance Share and In-Phase Component



Notes: The boxplots are based on the results for 47 prefectures in the period 1892-1937. The horizontal lines mark the minimum, 25th percentile, median, 75th percentile, and maximum (bottom to top).

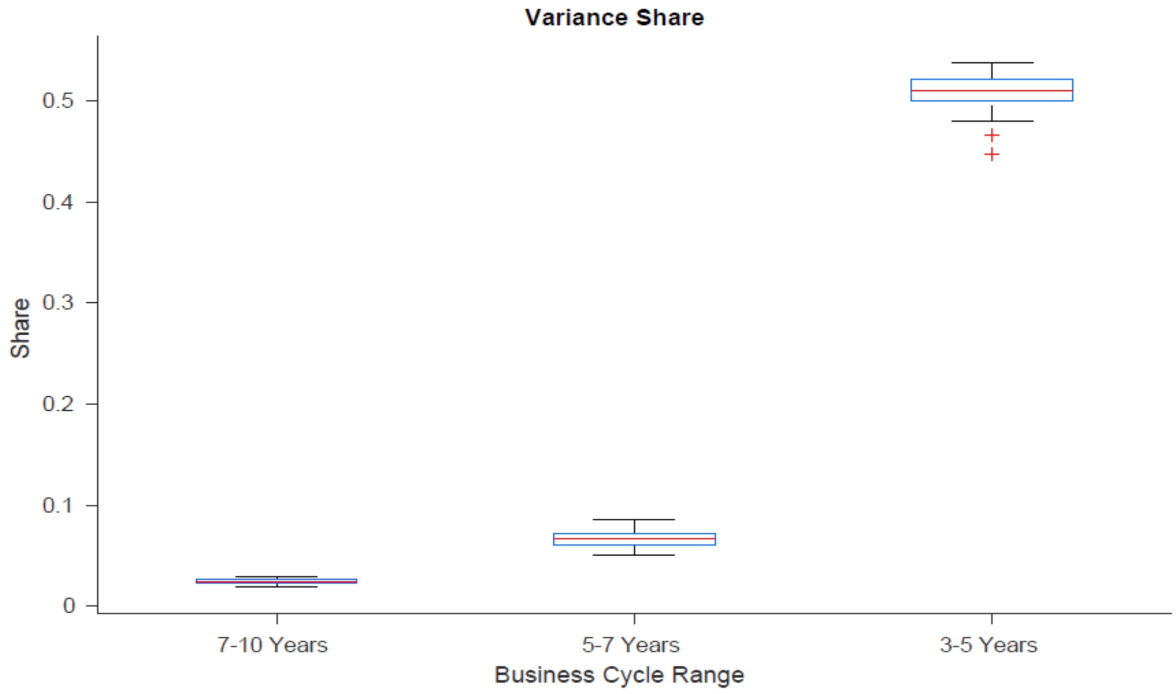
Figure 6: Variance Share and In-Phase Component by Frequency Interval (HP Filter)

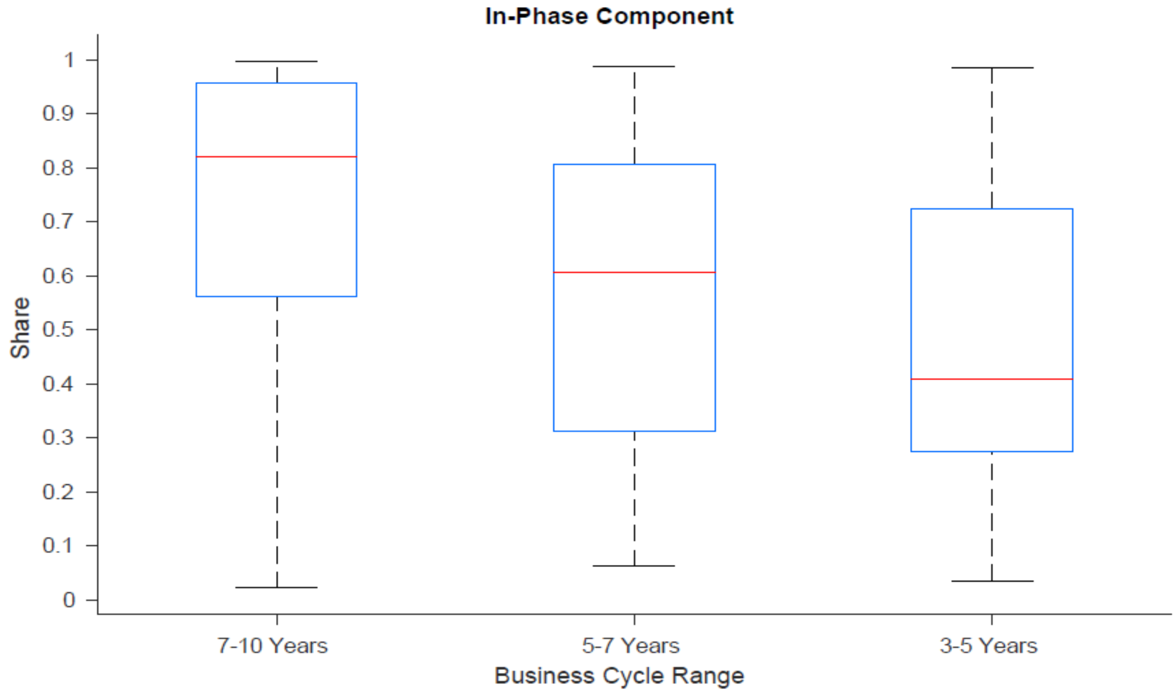




Notes: The boxplots are based on the results for 47 prefectures in the period 1892-1937. The horizontal lines mark the minimum, 25th percentile, median, 75th percentile, and maximum (bottom to top).

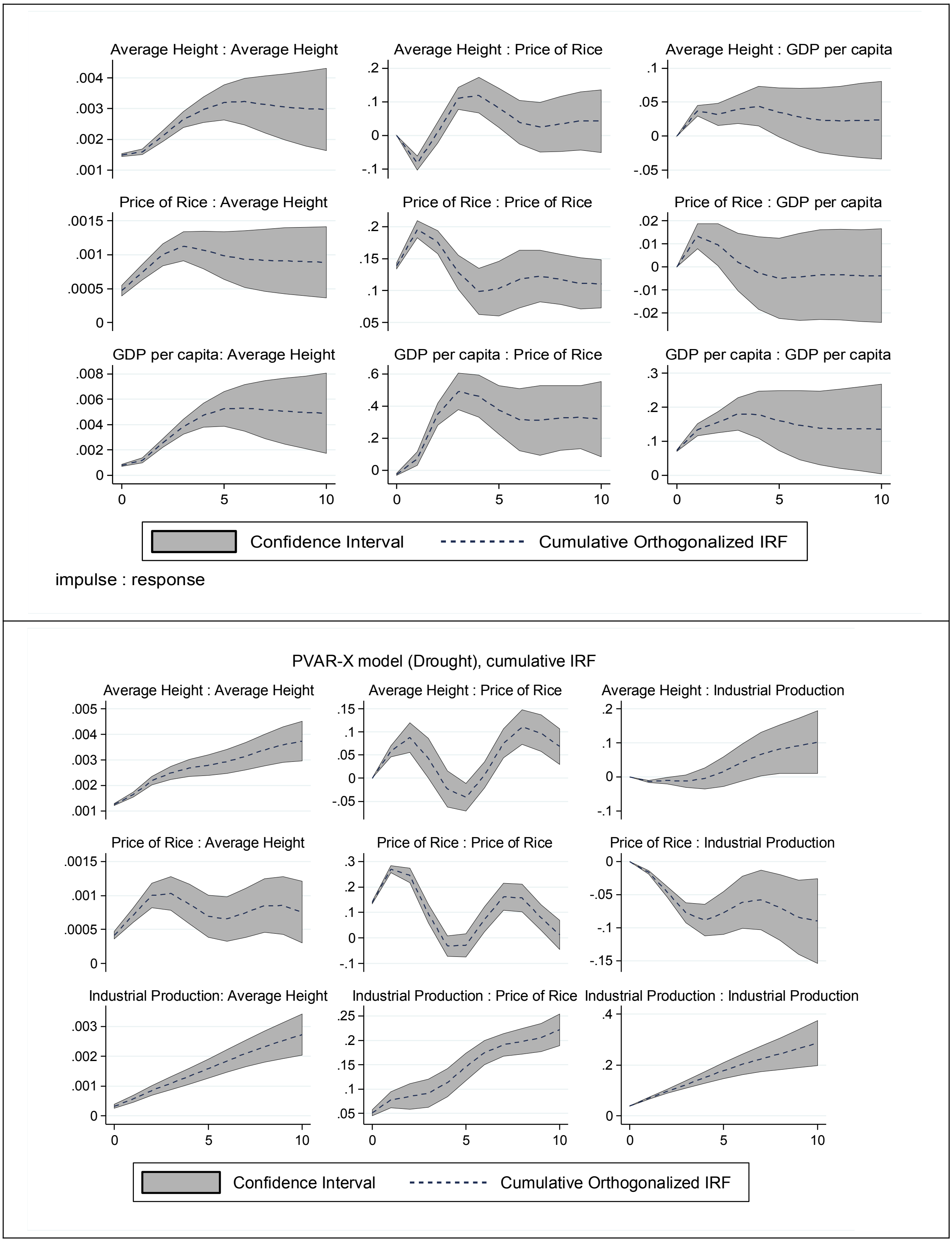
Figure 7: Variance Share and In-Phase Component by Frequency Interval (Difference Filter)





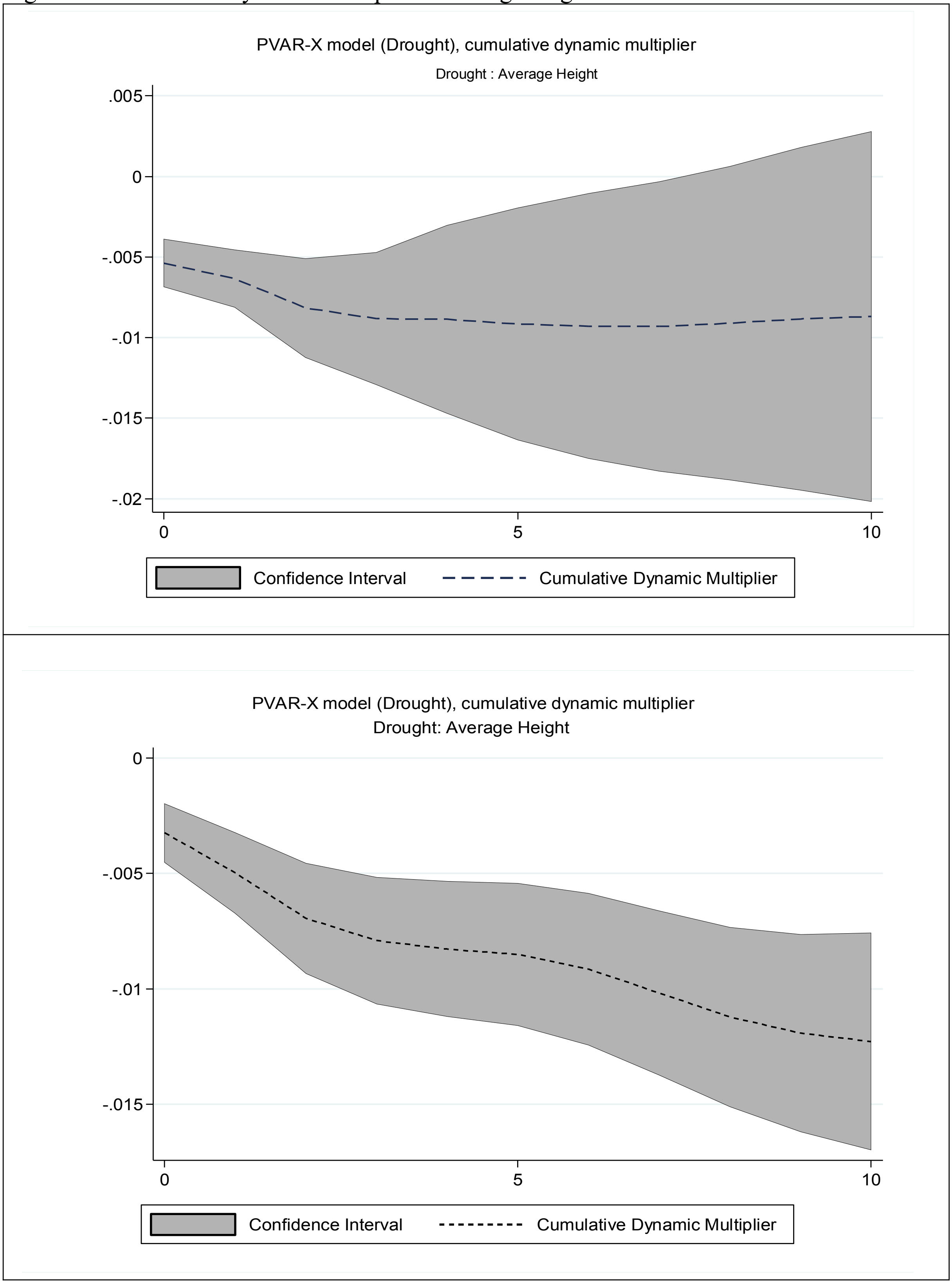
Note: The boxplots are based on the results for 47 prefectures in the period 1892-1937. The horizontal lines mark the minimum, 25th percentile, median, 75th percentile, and maximum (bottom to top).

Figure 8a – Orthogonalized cumulative impulse response function – average height models



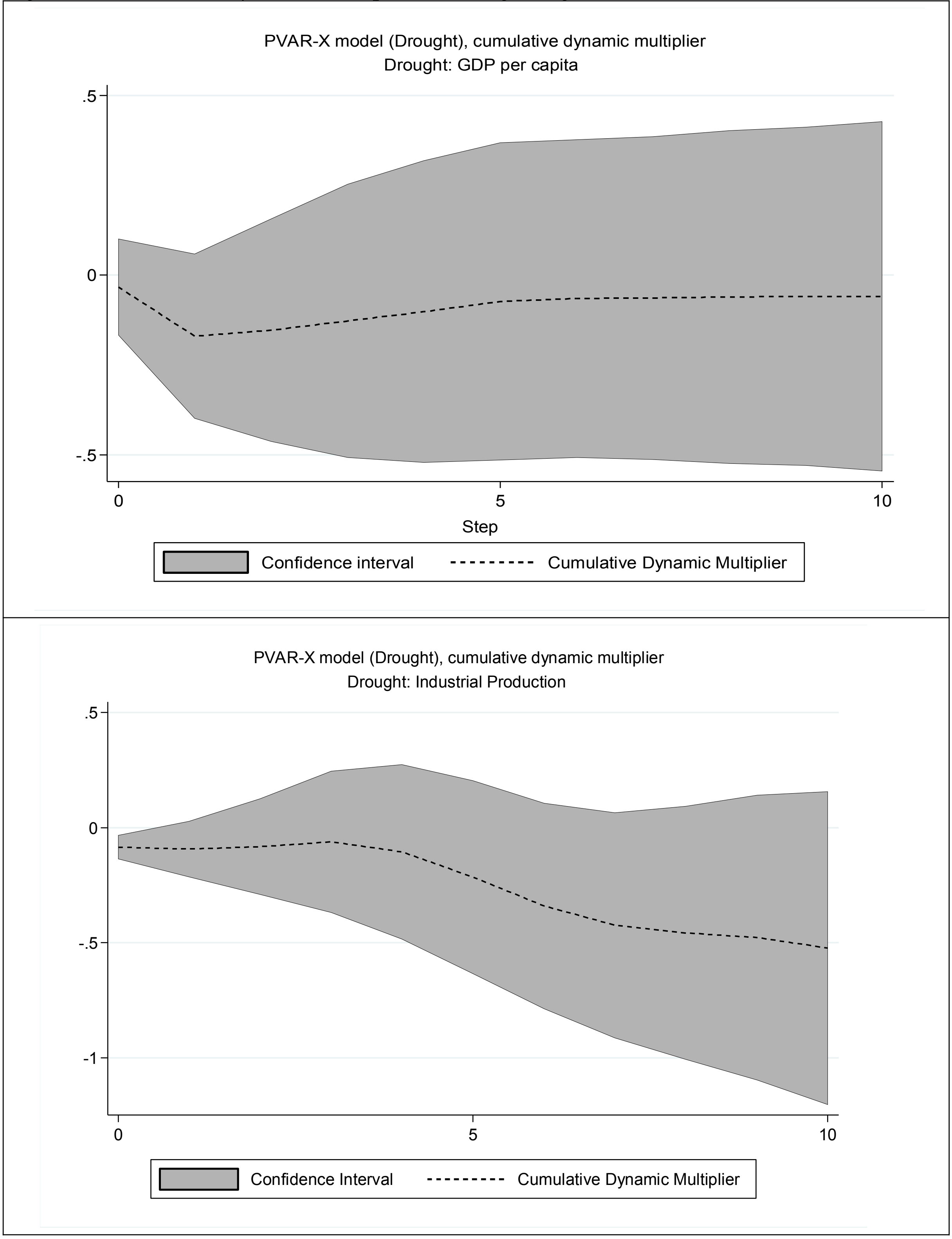
Note: this figure shows the two sets of cumulative orthogonalized IRF obtained after PVAR-X estimation using Drought as the climate (exogenous) variable. The upper specification uses real GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse:response.

Figure 8b Cumulative dynamic multiplier – average height models



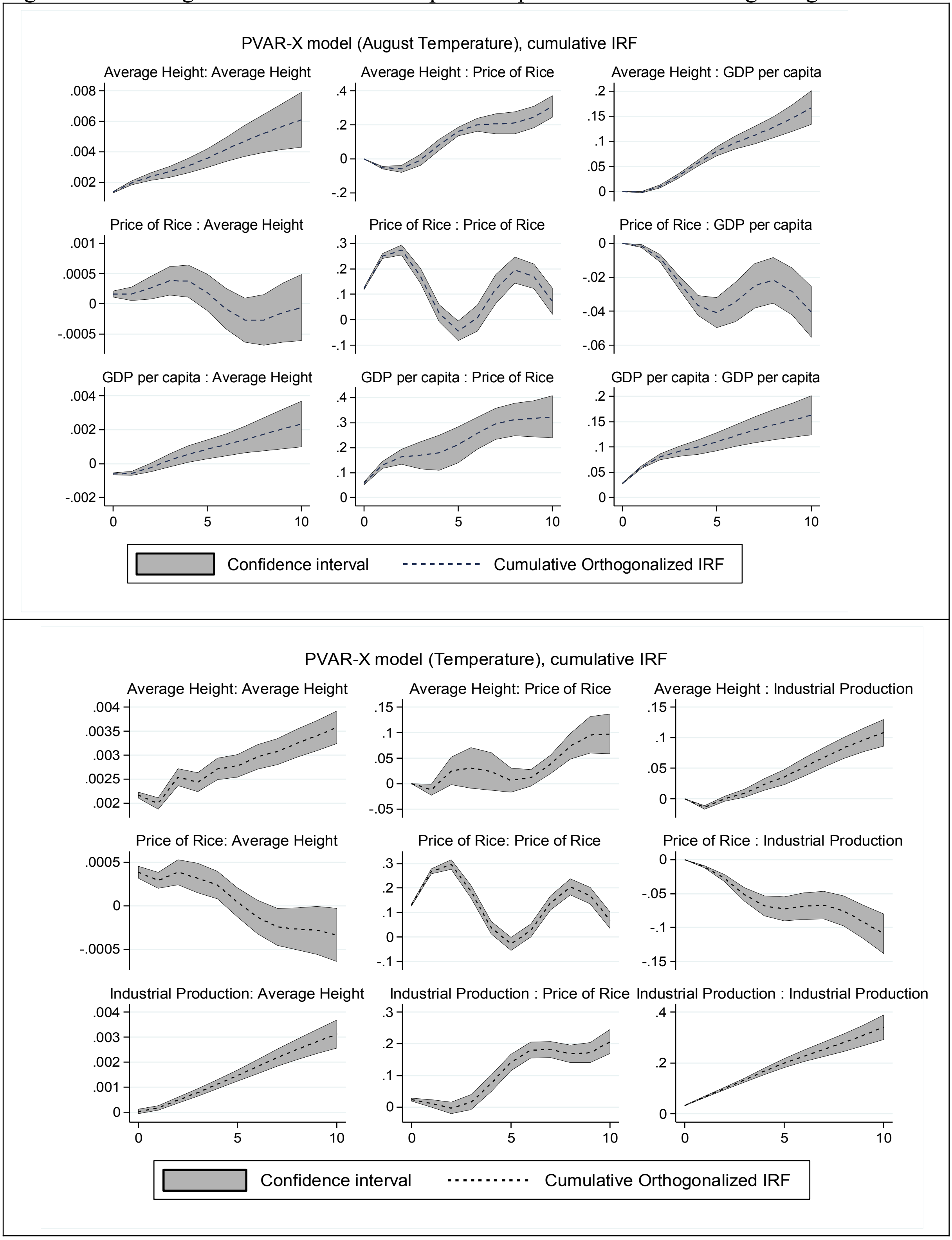
Note: this figure show the dynamic response of Average Height to an exogenous impulse on Drought. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse: response.

Figure 8c Cumulative dynamic multiplier – average height models



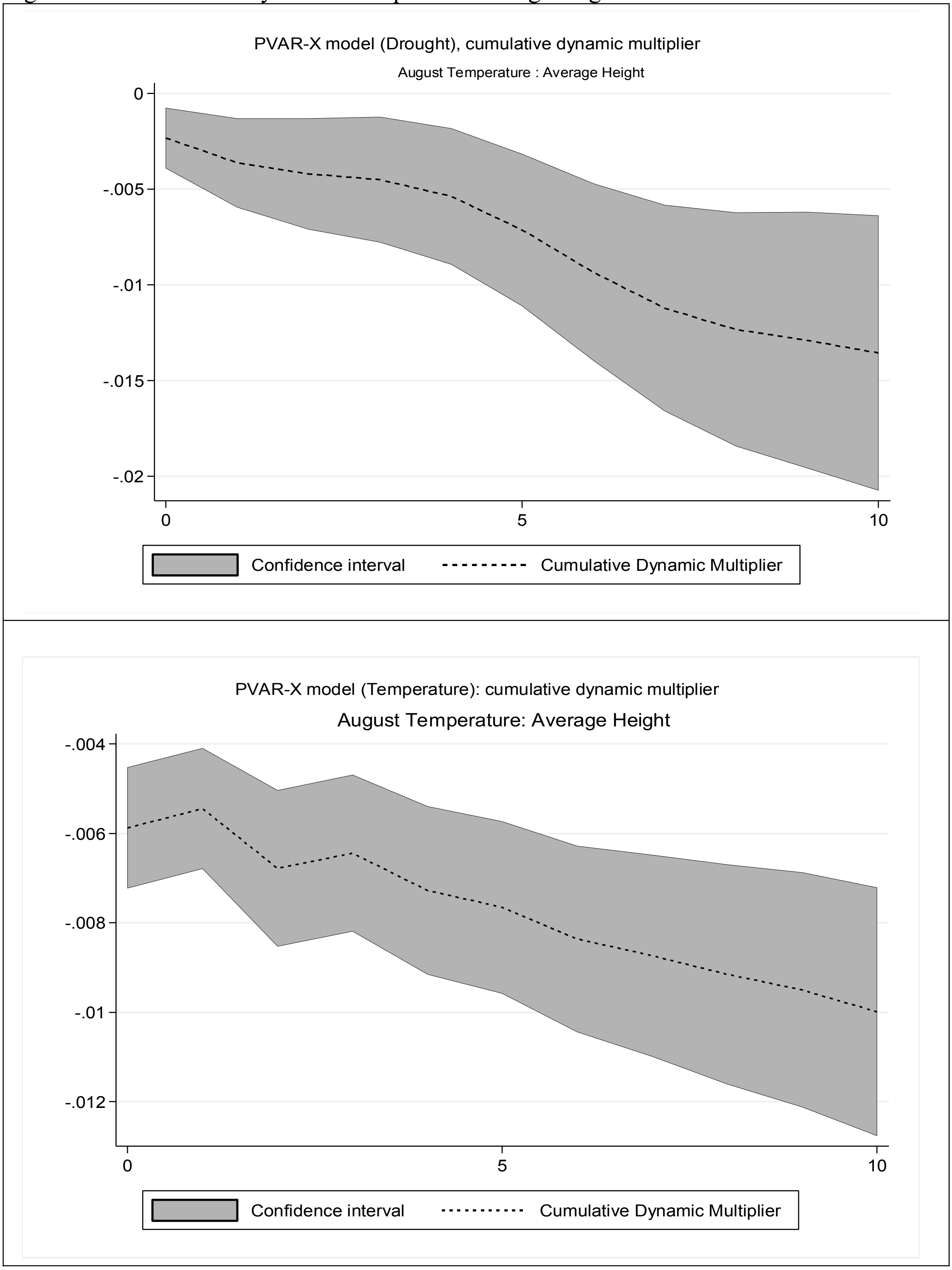
Note: this figure shows the dynamic response of the macroeconomic cycle to an exogenous impulse on Drought. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse: response.

Figure 9a – Orthogonalized cumulative impulse response function – average height models



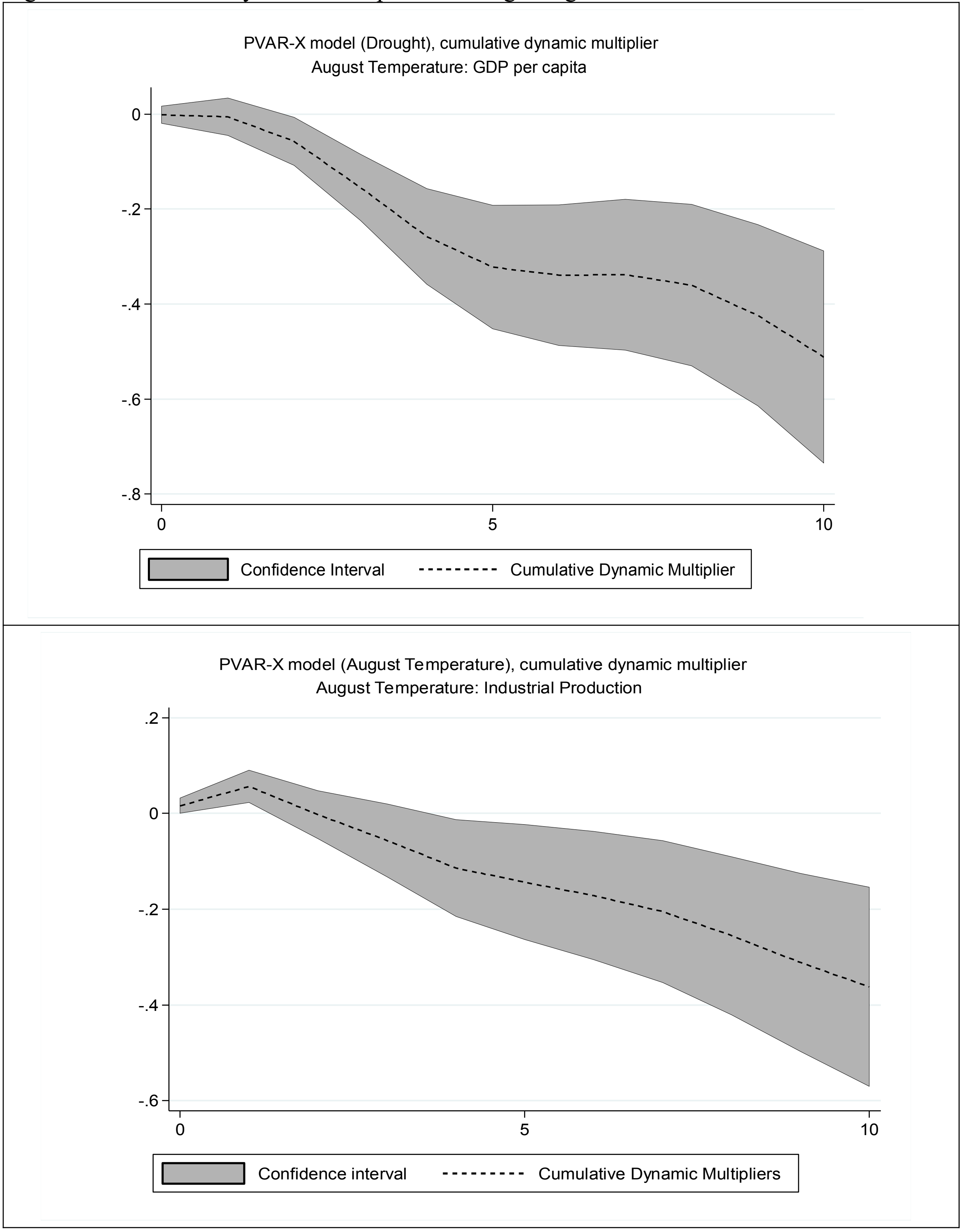
Note: this figure shows the two sets of cumulative orthogonalized IRF obtained after PVAR-X estimation using August Temperature as the climate (exogenous) variable. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse:response.

Figure 9b – Cumulative dynamic multipliers – average height models



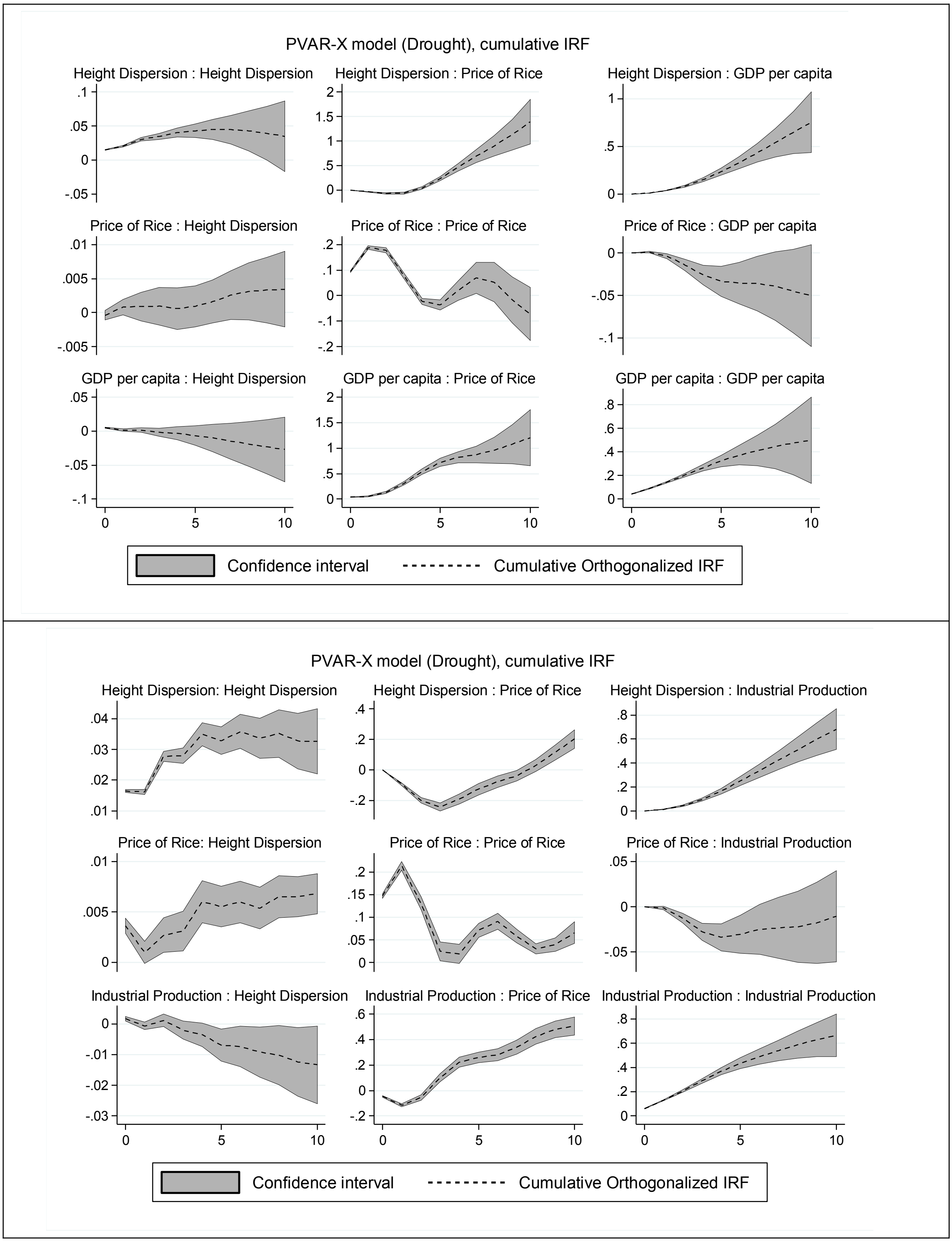
Note: this figure show the dynamic response of Average Height to an exogenous impulse on August Temperature. The upper specification uses GDP per capita as a measure for the business cycle and the lower one uses the national industrial production index. The figure reads impulse: response.

Figure 9c Cumulative dynamic multiplier – average height models



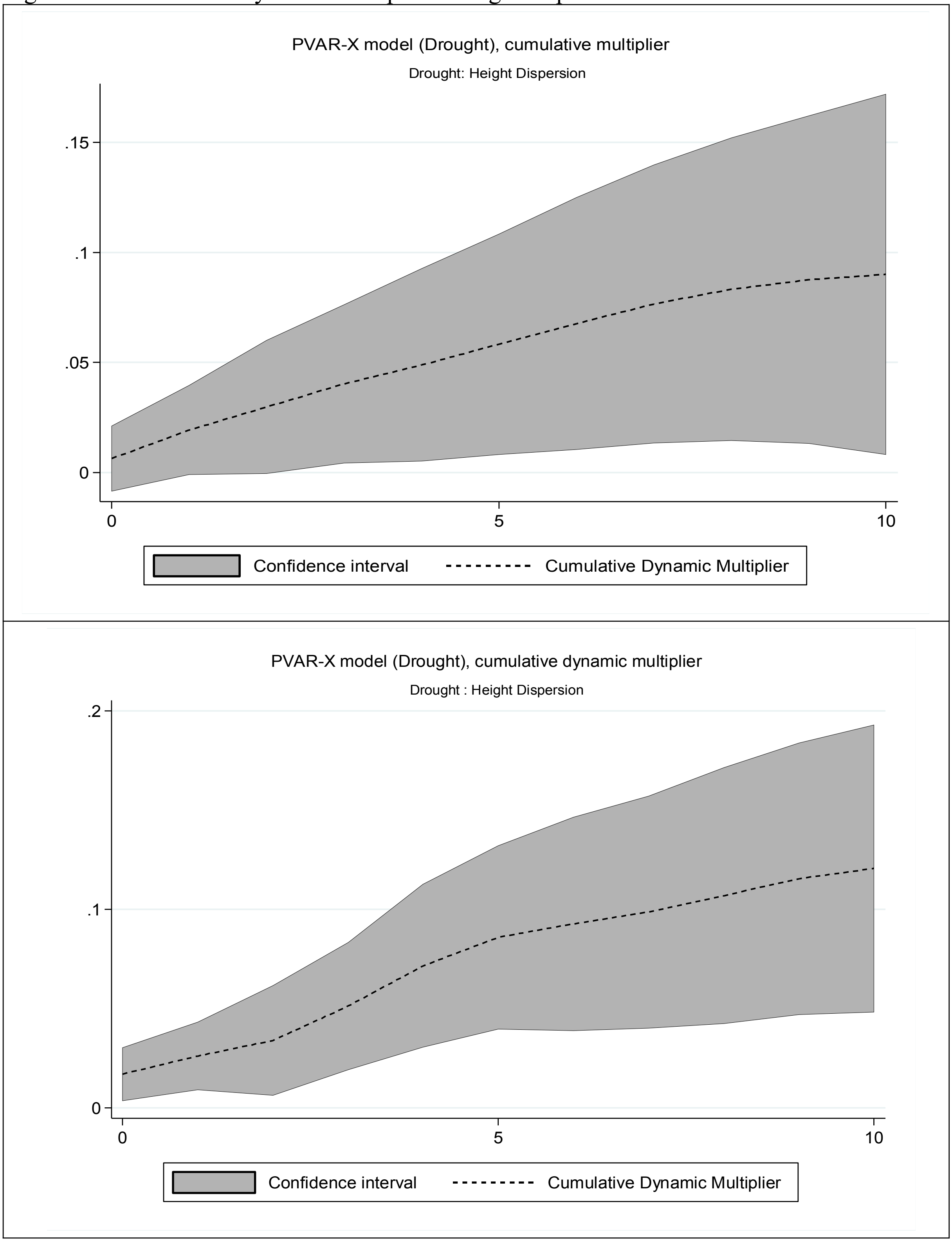
Note: this figure shows the dynamic response of the macroeconomic cycle to an exogenous impulse on August Temperature. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse: response.

Figure 10a – Orthogonalized cumulative impulse response function – height dispersion models



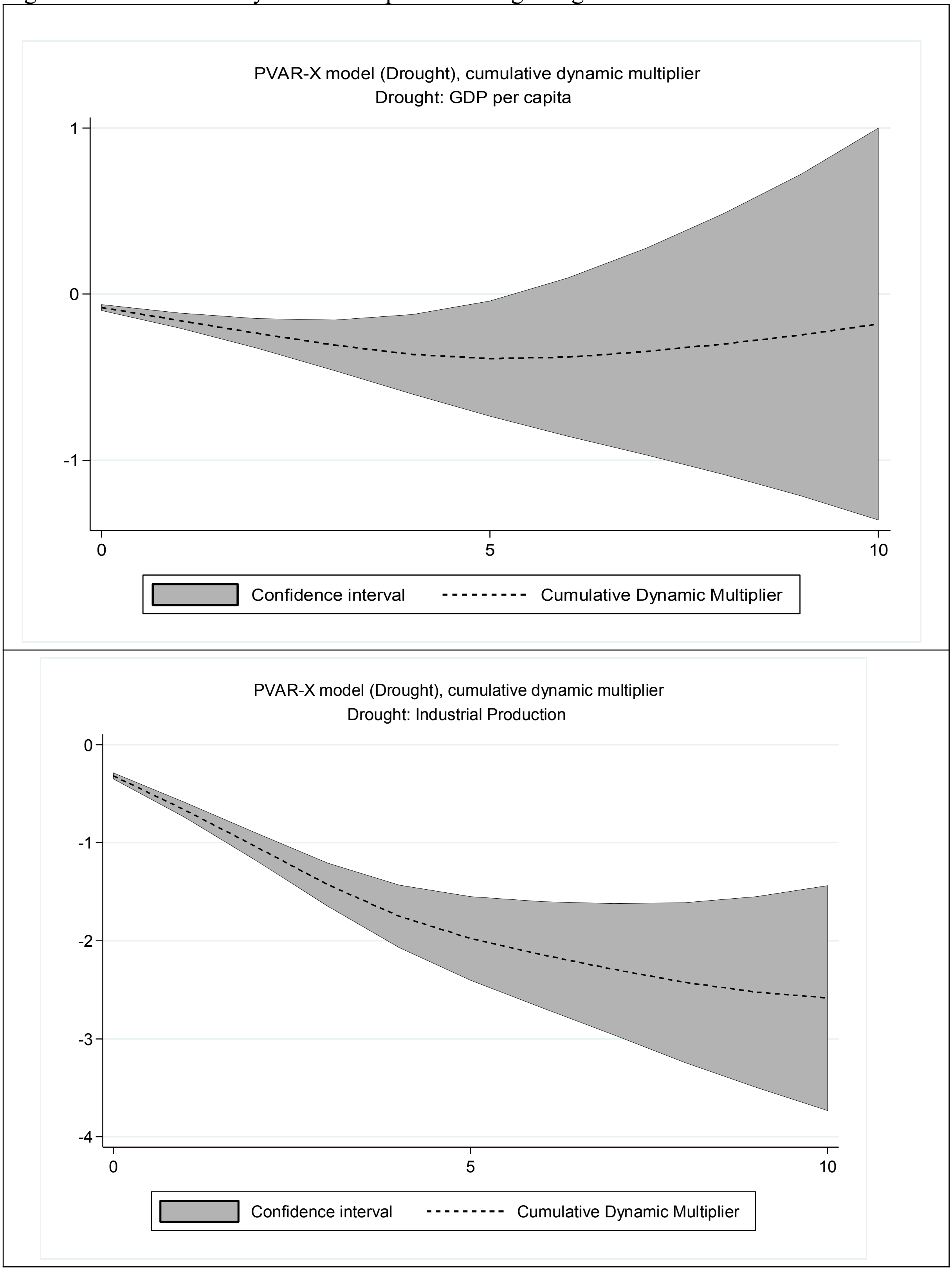
Note: this figure shows the two sets of cumulative orthogonalized IRF obtained after PVAR-X estimation using Drought as the climate (exogenous) variable. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse:response.

Figure 10b Cumulative dynamic multiplier – height dispersion models



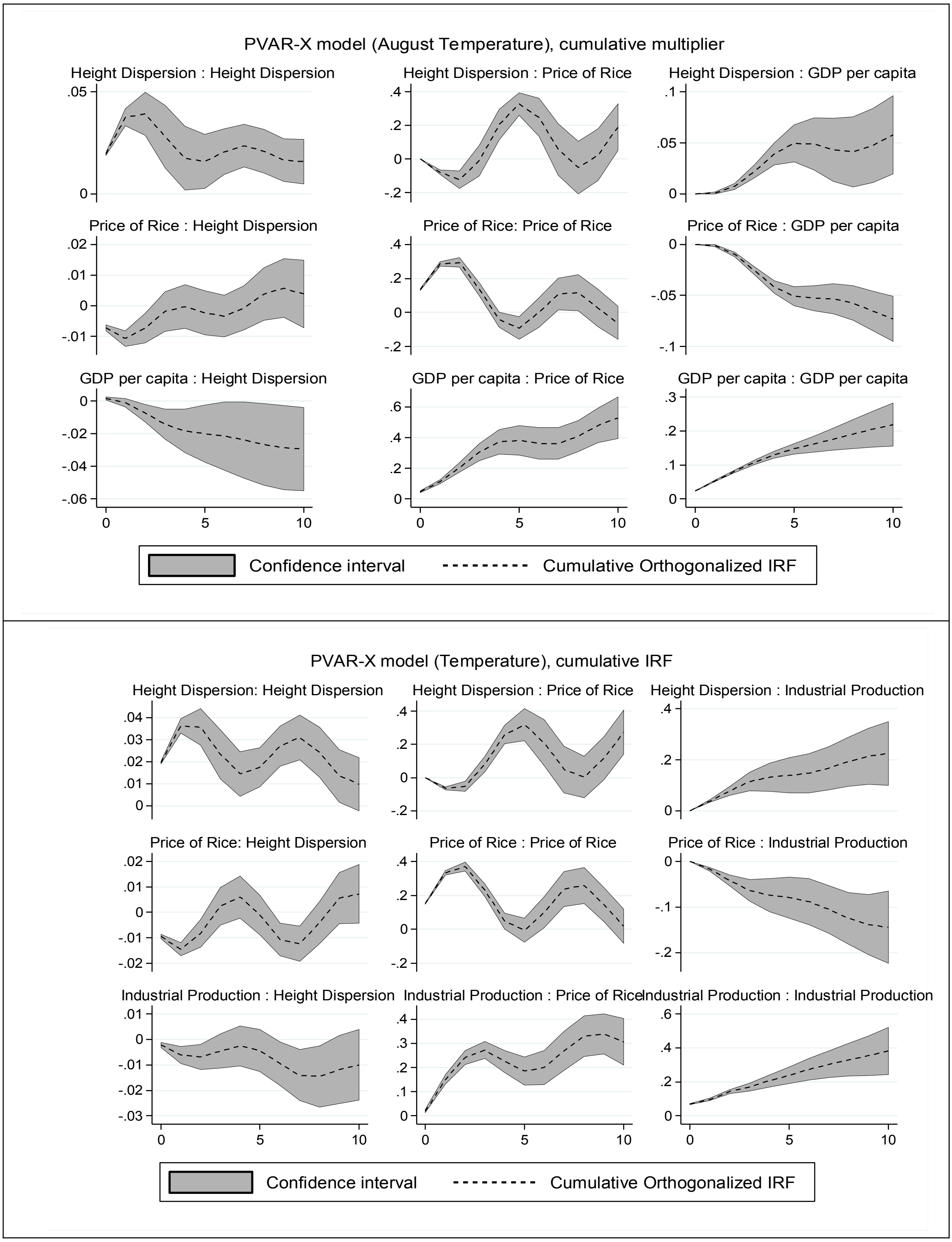
Note: this figure show the dynamic response of Height Dispersion to an exogenous impulse on August Temperature. The upper specification uses GDP per capita as a measure for the business cycle and the lower one uses the national industrial production index. The figure reads impulse: response.

Figure 10c Cumulative dynamic multiplier – average height models



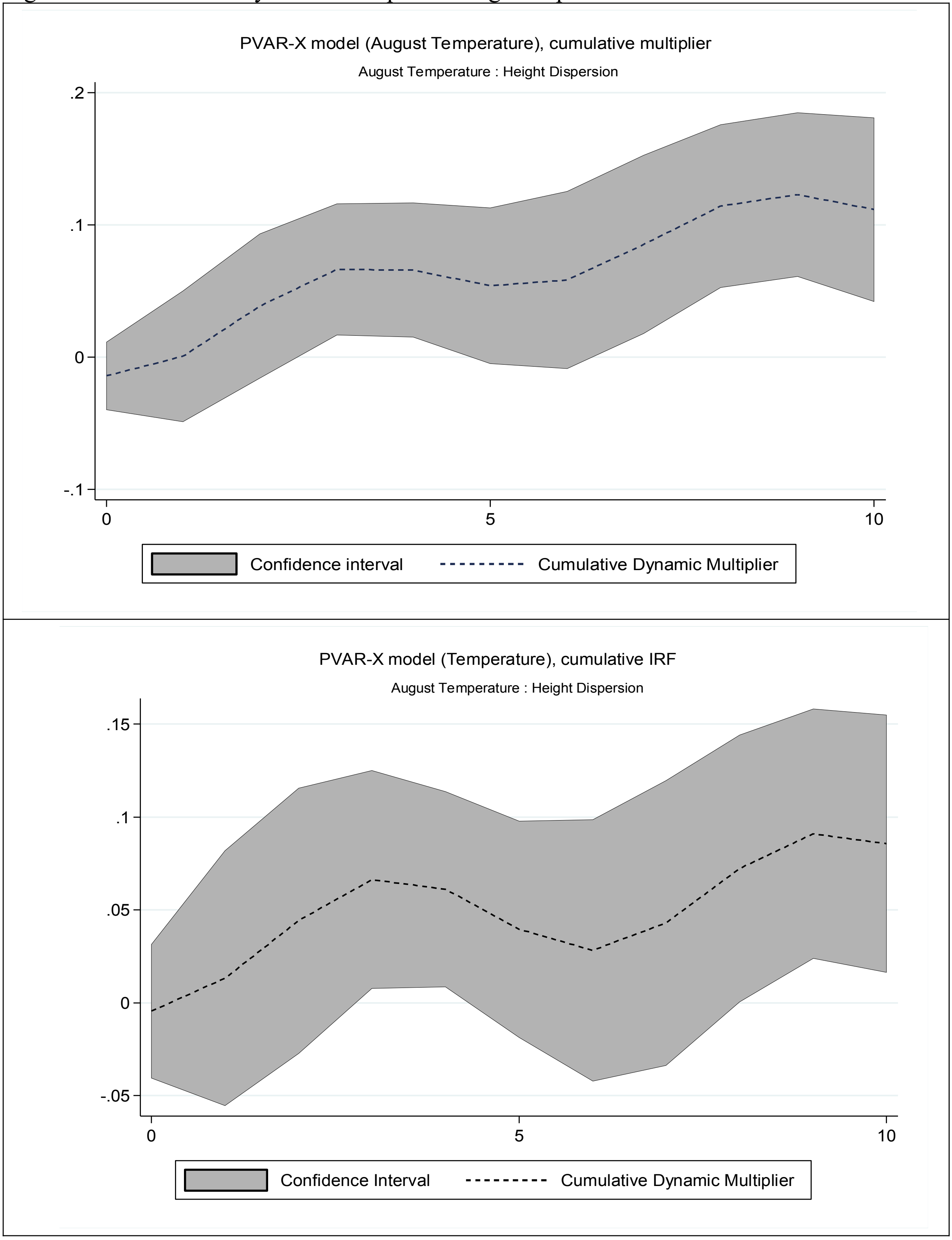
Note: this figure shows the dynamic response of the macroeconomic cycle to an exogenous impulse on Drought. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse: response.

Figure 11a – Orthogonalized cumulative impulse response function – height dispersion models



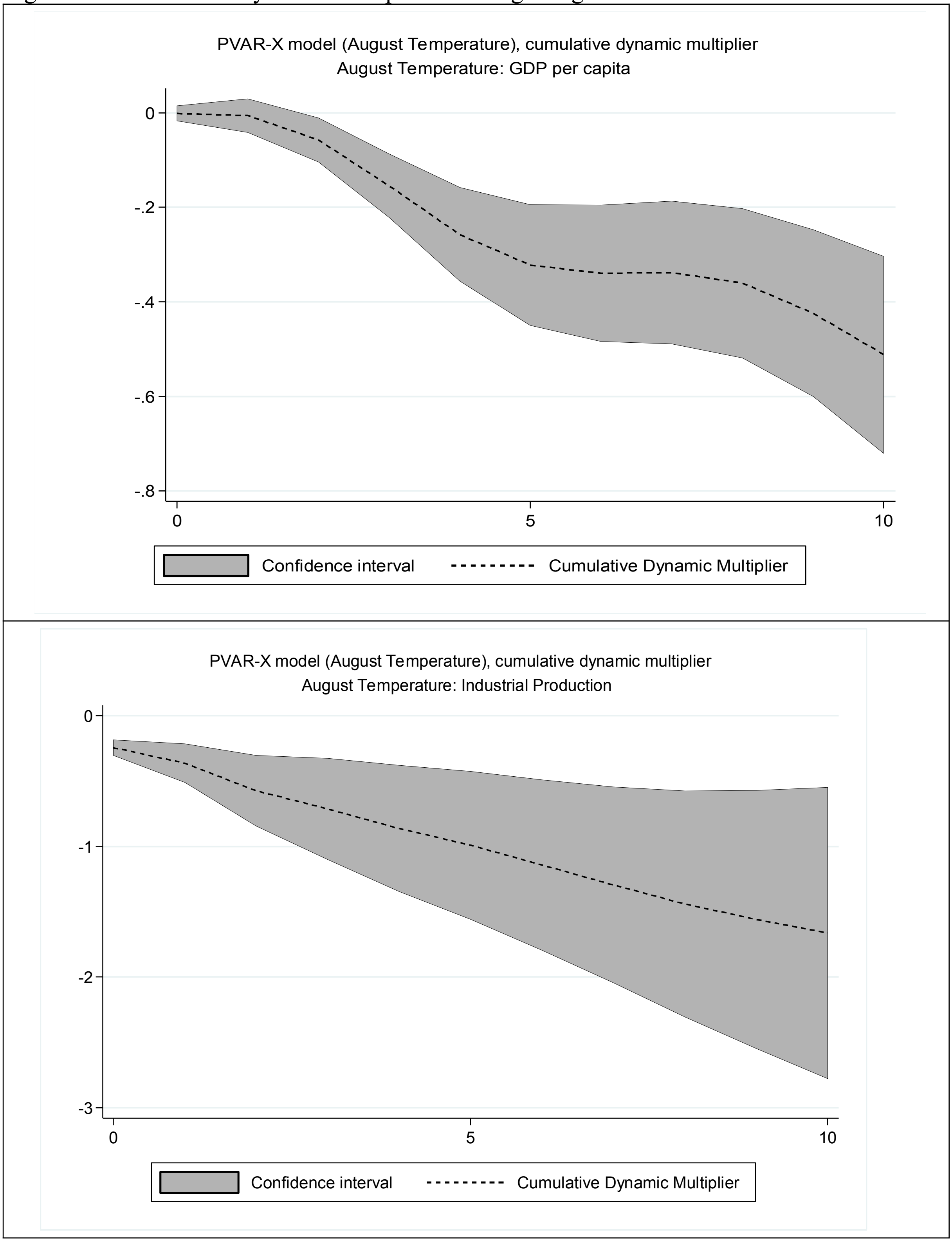
Note: this figure shows the two sets of cumulative orthogonalized IRF obtained after PVAR-X estimation using Drought as the climate (exogenous) variable. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse:response.

Figure 11b Cumulative dynamic multiplier – height dispersion models



Note: this figure show the dynamic response of Height Dispersion to an exogenous impulse on August Temperature. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse: response.

Figure 11c Cumulative dynamic multiplier – average height models



Note: this figure shows the dynamic response of the macroeconomic cycle to an exogenous impulse on August Temperature. The upper specification uses GDP per capita as a measure for the business cycle, and the lower one uses the national industrial production index. The figure reads impulse: response.

FOR ONLINE PUBLICATION - APPENDIX

This appendix provides methodological detail and robustness checks backing up the results displayed in the body of the paper. It is divided into two sections. Section A1 describes the spectral analysis method used in section 4 of the paper. Section A2 estimates the effect of climate anomalies on average stature and dispersion using a dynamic panel analysis with alternate estimators.

A1: Spectral analysis methodology

The spectral density matrix $F(\lambda)$of a VAR(p)-model is given by

$$F(\lambda)=\frac{1}{2\pi}A(\lambda)^{-1}\Sigma A(\lambda)^{-¿},\lambda\in[-0.5,0.5],$$

where Σ is the variance-covariance matrix of the errors, and $A(\lambda)$ is the Fourier transform of the matrix lag polynomial $A(L)=I-A_1L-A_2L^2-\cdots-A_pL^p$. In our case, we analyze the co-movement of a time series of average height, x_t, and a business cycle indicator, y_t. It is straightforward to stay in time domain and look at the covariance matrices $\Gamma(\tau)_{xy},\tau=0,\pm1,\pm2,\ldots$, but the spectral density matrix is just the Fourier transform of the covariance matrix, and allows to analyze co-movement in frequency bands of interest.[1] Integrating the diagonal elements of the spectral density matrix $f_j(\lambda),j=x,y$(autospectra), over the interval $[-0.5,0.5]$ gives the variances of the individual series. The off-diagonal elements, the cross-spectra, are complex numbers given by $f_{xy}(\lambda)=c_{xy}(\lambda)-i\,q_{xy}(\lambda)$, where the co-spectrum $c_{xy}(\lambda)$ measures the in-phase components of x_t and y_t at a certain frequency λ, while the quadrature spectrum $q_{xy}(\lambda)$ measures the out-of-phase components. Combining these measures with the autospectra gives squared coherency$sc_{xy}(\lambda)$, a measure similar to R^2in linear regression analysis:

$$sc_{xy}(\lambda)=\frac{|f_{xy}(\lambda)|^2}{f_x(\lambda)f_y(\lambda)},0\le sc_{xy}(\lambda)\le1.$$

This measures assesses the degree of linear relationship between two series, frequency by frequency.

If we want to measure the extent to which the variance of cyclical components of the height series x_t in a specific frequency band $[\lambda_1,\lambda_2]$ can be attributed to the corresponding cyclical components in the business cycle indicator y_t, squared coherency $sc_{xy}(\lambda)$ can be used to decompose the variance of the height series in this frequency band into an "explained" and a residual part:

$$\int_{\lambda_1}^{\lambda_2}f_x(\lambda)d\lambda=¿\int_{\lambda_1}^{\lambda_2}sc_{xy}(\lambda)f_x(\lambda)d\lambda+¿\int_{\lambda_1}^{\lambda_2}f_u(\lambda)d\lambda.¿¿$$

Croux, Forni and Reichlin (2001) propose to calculate dynamic correlation $q_{xy}(\lambda)$ instead, a measure which focusses on the information contained in the co-spectrum, and hence, on the correlation of the in-phase components of the series of interest:

$$\rho_{xy}(\lambda)=\frac{c_{xy}(\lambda)}{f_x(\lambda)f_y(\lambda)}.$$

We can use this idea to further decompose $f_x(\lambda)$ in the interval $[\lambda_1,\lambda_2]$:

$$\int_{\lambda_1}^{\lambda_2}f_x(\lambda)d\lambda=¿\int_{\lambda_1}^{\lambda_2}\frac{c_{xy}(\lambda)^2+q_{xy}(\lambda)^2}{f_x(\lambda)f_y(\lambda)}f_x(\lambda)d\lambda+¿\int_{\lambda_1}^{\lambda_2}f_u(\lambda)d\lambda=¿\int_{\lambda_1}^{\lambda_2}\frac{c_{xy}(\lambda)^2}{f_y(\lambda)}d\lambda+¿\int_{\lambda_1}^{\lambda_2}\frac{q_{xy}(\lambda)^2}{f_y(\lambda)}d\lambda+¿\int_{\lambda_1}^{\lambda_2}f_u(\lambda)d\lambda.¿¿¿¿¿$$

---

[1] See e.g. Priestley (1981), Harvey (1993, 175-179) and Hamilton (1994, 152-179).

Hence, we can distinguish between the in-phase component and the out-of-phase component of the variance of height attributable to fluctuations in the business cycle indicator in a frequency interval of interest.

To assess the robustness of our results, we follow Canova (1998) and compare the outcome for different filters. Because it is widely used, we apply the Hodrick and Prescott (1997) procedure, which has well-known problems. The most recent critique is Hamilton (2016), and therefore we use his alternative as well, together with the Baxter and King (1999) filter in the modified version proposed in A'Hearn and Woitek (2001), as well as the difference filter.

A2: Estimating the impact of climate anomalies in a dynamic panel framework

The tables control for the impact of climate anomalies on average height and height dispersion using a dynamic panel framework with three estimators: OLS, fixed effects, and system GMM, following guidelines provided in Roodman (2009). For each SGMM model, the parameter of the lagged dependent variable estimated with SGMM lies between OLS and FE values. In addition, all models satisfy over-identifying restrictions conditions, while avoiding excessively high p-values of the Hansen statistics. The results presented in table A3a confirm the findings obtained in the paper: in all estimations, droughts and abnormally high summer temperatures exert a negative and significant impact on average height. Inspection of table A3b also confirms the positive effect of droughts and abnormally high summer temperature anomalies on height dispersion.

Table A2a: Height models: estimation results with climate data and prefecture fixed effect regressions, dynamic panel

	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM
Height (-1)	0.980***	0.867***	0.902***	0.980***	0.866***	0.898***	0.980***	0.866***	0.902***	0.980***	0.867***	0.902***
	(133.6)	(52.35)	(50.51)	(133.2)	(52.25)	(45.41)	(133.4)	(52.24)	(49.55)	(133.6)	(52.39)	(50.45)
Interaction				0.0470	-0.00311	0.704						
				(0.0767)	(-0.00497)	(0.544)						
Drought	-0.140	-0.191**	-0.351***	-0.142	-0.196**	-0.323**	-0.139	-0.191**	-0.346***	-0.142	-0.192**	-0.351***
	(-1.566)	(-2.095)	(-3.050)	(-1.552)	(-2.112)	(-2.793)	(-1.562)	(-2.092)	(-3.049)	(-1.591)	(-2.105)	(-3.005)
Soy price	-0.065	0.071	0.094	-0.064	0.073	0.108	-0.065	0.070	0.090	-0.067	0.068	0.090
	(-1.185)	(1.148)	(1.182)	(-1.171)	(1.152)	(1.452)	(-1.194)	(1.137)	(1.091)	(-1.217)	(1.100)	(1.123)
Rice price	0.207***	0.321***	0.175**	0.207***	0.322***	0.170**	0.206***	0.322***	0.180**	0.208***	0.324***	0.175**
	(3.569)	(5.016)	(2.324)	(3.555)	(4.986)	(2.315)	(3.560)	(5.032)	(2.442)	(3.594)	(5.053)	(2.433)
Barley price	-0.085**	-0.059	-0.011	-0.085**	-0.059	-0.005	-0.085**	-0.059	-0.017	-0.088**	-0.061	-0.002
	(-2.033)	(-1.256)	(-0.220)	(-2.013)	(-1.266)	(-0.102)	(-2.027)	(-1.261)	(-0.346)	(-2.087)	(-1.325)	(-0.0525)
January							0.011	0.014	0.022			
							(0.811)	(1.085)	(1.227)			
February										0.022	0.018	-0.028
										(1.450)	(1.265)	(-0.671)
Constant	3.005***	20.46***	15.04***	3.014***	20.46***	15.61***	3.046***	20.60***	15.04***	3.060***	20.44***	15.07***
	(2.646)	(8.036)	(5.468)	(2.648)	(8.022)	(5.120)	(2.679)	(8.082)	(5.370)	(2.697)	(8.032)	(5.480)
Observations	485	485	485	484	484	484	485	485	485	485	485	485
R2 overall	0.981	0.976		0.981	0.976		0.981	0.963		0.981	0.963	
R-squared between		0.999			0.999			0.999			0.999	
R-squared within		0.963			0.963			0.963			0.963	
Number of prefecture		17	17		17	17		17	17		17	17
Number of instruments			16			19			19			19
Hansen statistic			13.49			13.27			13.34			15.10
p value of Hansen statistic			0.198			0.350			0.345			0.236
Arellano-Bond test for AR(1)			-3.909			-3.908			-3.840			-3.901
p value for AR(1)			9.28e-05			9.29e-05			0.000123			9.58e-05
Arellano-Bond test for AR(2)			1.609			1.626			1.190			1.720
p value for AR(2)			0.108			0.104			0.234			0.085

Table A2a (continued): Height models: estimation results with climate data and prefecture fixed effect regressions, dynamic panel

	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM
Height(-1)	0.980***	0.867***	0.903***	0.980***	0.867***	0.897***	0.980***	0.865***	0.903***	0.982***	0.872***	0.908***	0.981***	0.869***	0.885***
	(133.5)	(52.33)	(48.53)	(133.8)	(52.41)	(49.68)	(133.3)	(51.95)	(51.96)	(134.4)	(52.31)	(42.08)	(133.9)	(51.05)	(36.03)
Drought	-0.142	-0.192**	-0.368***	-0.152*	-0.200**	-0.299**	-0.140	-0.192**	-0.361***	-0.123	-0.172*	-0.343**	-0.112	-0.180*	-0.371**
	(-1.589)	(-2.109)	(-3.187)	(-1.695)	(-2.188)	(-2.450)	(-1.563)	(-2.101)	(-3.175)	(-1.385)	(-1.890)	(-2.900)	(-1.249)	(-1.945)	(-2.591)
Soy price	-0.062	0.074	0.108	-0.061	0.0727	0.132*	-0.065	0.075	0.097	-0.048	0.082	0.107	-0.047	0.075	0.060
	(-1.124)	(1.194)	(1.394)	(-1.110)	(1.176)	(1.969)	(-1.190)	(1.199)	(1.178)	(-0.870)	(1.322)	(1.427)	(-0.848)	(1.199)	(0.691)
Rice price	0.205***	0.320***	0.160*	0.209***	0.324***	0.167**	0.207***	0.322***	0.171**	0.187***	0.299***	0.159*	0.174***	0.308***	0.271**
	(3.536)	(4.985)	(2.049)	(3.614)	(5.062)	(2.209)	(3.567)	(5.024)	(2.214)	(3.221)	(4.622)	(1.850)	(2.906)	(4.569)	(2.479)
Barley price	-0.086**	-0.059	-0.008	-0.089**	-0.062	-0.018	-0.085**	-0.060	-0.012	-0.077*	-0.050	-0.018	-0.075*	-0.055	-0.030
	(-2.052)	(-1.276)	(-0.161)	(-2.123)	(-1.341)	(-0.343)	(-2.021)	(-1.290)	(-0.237)	(-1.837)	(-1.089)	(-0.359)	(-1.777)	(-1.174)	(-0.553)
March	0.018	0.017	0.053												
	(0.803)	(0.776)	(1.128)												
April				0.148	0.123	0.049									
				(1.566)	(1.359)	(0.273)									
May							0.022	-0.097	-0.054						
							(0.131)	(-0.598)	(-0.132)						
June										-0.431***	-0.317**	-0.146			
										(-2.819)	(-2.131)	(-0.412)			
July													-0.392**	-0.114	0.692
													(-2.076)	(-0.607)	(1.317)
Constant	3.015***	20.450***	14.940***	2.995***	20.350***	15.810***	2.996***	20.620***	14.920***	2.761**	19.670***	14.180***	2.858**	20.100***	17.670***
	(2.654)	(8.030)	(5.211)	(2.642)	(7.997)	(5.673)	(2.632)	(8.049)	(5.602)	(2.442)	(7.672)	(4.270)	(2.521)	(7.685)	(4.706)
Observations	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485
R2 overall	0.981	0.963		0.981	0.963		0.981	0.975		0.981	0.976		0.981	0.963	
R2 between		0.999			0.999			0.999			0.999			0.999	
R2 within		0.963			0.963			0.963			0.964			0.963	
Number of prefecture		17	17		17	17		17	17		17	17		17	17
Number of instruments			19			19			19			19			19
Hansen statistic			16.40			13.30			13.60			15.70			14.29
p value of Hansen statistic			0.174			0.348			0.327			0.205			0.283
Arellano-Bond test for AR(1)			-3.931			-3.915			-3.930			-3.908			-3.936
p value for AR(1)			8.45e-05			9.02e-05			8.51e-05			9.31e-05			8.28e-05
Arellano-Bond test for AR(2)			1.645			1.631			1.592			1.664			1.938
p value for AR(2)			0.100			0.103			0.111			0.0961			0.0526

Table A2a (continued): Height models: estimation results with climate data and prefecture fixed effect regressions, dynamic panel

	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM
Height (-1)	0.979***	0.866***	0.889***	0.980***	0.868***	0.924***	0.980***	0.862***	0.881***	0.982***	0.870***	0.924***	0.980***	0.866***	0.888***
	(134.2)	(52.71)	(55.90)	(133.9)	(52.05)	(40.66)	(133.0)	(50.73)	(34.69)	(133.9)	(51.97)	(39.46)	(133.5)	(52.32)	(48.53)
Drought	-0.110	-0.153*	-0.353***	-0.143	-0.191**	-0.434***	-0.144	-0.196**	-0.328**	-0.148*	-0.200**	-0.434***	-0.138	-0.188**	-0.359**
	(-1.232)	(-1.674)	(-3.156)	(-1.611)	(-2.099)	(-3.973)	(-1.604)	(-2.136)	(-2.634)	(-1.657)	(-2.184)	(-3.573)	(-1.543)	(-2.060)	(-2.918)
Soy price	-0.056	0.078	0.108	-0.0727	0.0639	0.000956	-0.0627	0.0715	0.131*	-0.0664	0.0686	0.0678	-0.0663	0.0691	0.150*
	(-1.038)	(1.270)	(1.420)	(-1.328)	(1.023)	(0.007)	(-1.141)	(1.154)	(1.766)	(-1.220)	(1.108)	(0.777)	(-1.213)	(1.117)	(2.045)
Rice price	0.195***	0.309***	0.209**	0.203***	0.319***	0.174*	0.206***	0.328***	0.187**	0.208***	0.318***	0.175**	0.209***	0.325***	0.179**
	(3.374)	(4.855)	(2.635)	(3.514)	(4.966)	(2.016)	(3.543)	(5.096)	(2.535)	(3.600)	(4.973)	(2.120)	(3.607)	(5.073)	(2.344)
Barley price	-0.0872**	-0.0601	-0.0414	-0.0821*	-0.0568	-0.00817	-0.0868**	-0.0539	-0.00616	-0.0919**	-0.0651	-0.0562	-0.0855**	-0.0582	-0.0370
	(-2.087)	(-1.306)	(-0.730)	(-1.956)	(-1.226)	(-0.176)	(-2.057)	(-1.156)	(-0.119)	(-2.190)	(-1.401)	(-0.939)	(-2.034)	(-1.258)	(-0.706)
August	-0.611***	-0.616***	-0.484												
	(-2.667)	(-2.801)	(-1.033)												
September				-0.277*	-0.134	-0.802									
				(-1.726)	(-0.861)	(-1.714)									
October							-0.069	0.168	0.419						
							(-0.454)	(1.130)	(0.968)						
November										-0.121**	-0.073	-0.233			
										(-2.442)	(-1.511)	(-1.319)			
December													0.021	0.023	0.115**
													(1.125)	(1.325)	(2.874)
Constant	3.151***	20.530***	17.070***	3.016***	20.200***	11.720***	2.978***	21.130***	18.230***	2.798**	19.860***	11.730***	3.045***	20.570***	17.230***
	(2.789)	(8.122)	(6.951)	(2.662)	(7.876)	(3.381)	(2.611)	(8.082)	(4.668)	(2.467)	(7.710)	(3.278)	(2.681)	(8.081)	(6.101)
Observations	485	485	485	485	485	485	484	484	484	484	484	484	485	485	485
R2 overall	0.981	0.964		0.981	0.976		0.981	0.975		0.981	0.976		0.981	0.963	
R2 between		0.999			0.999			0.999			0.999			0.999	
R2 within		0.964			0.963			0.963			0.963			0.963	
Number of prefecture		17	17		17	17		17	17		17	17		17	17
Number of instruments			19			19			19			19			19
Hansen statistic			15.13			15.03			12.95			15.06			13.39
p value of Hansen statistic			0.235			0.240			0.373			0.238			0.341
Arellano-Bond test for AR(1)			-3.912			-3.811			-3.848			-3.877			-3.904
p value for AR(1)			9.14e-05			0.000138			0.000119			0.000106			9.45e-05
Arellano-Bond test for AR(2)			2.072			1.396			1.464			1.306			1.645
p value for AR(2)			0.038			0.163			0.143			0.192			0.099

Note: t statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.10

Table A2b: Height dispersion models: estimation results with climate data and prefecture fixed effect regressions, dynamic panel

	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM
Dispersion (-1)	0.907***	0.770***	0.804**	0.907***	0.771***	0.825**	0.907***	0.774***	0.815**	0.908***	0.773***	0.782***
	(53.43)	(23.56)	(7.060)	(53.31)	(23.51)	(7.552)	(53.77)	(23.76)	(6.904)	(53.50)	(23.56)	(6.424)
Interaction				-0.001	-0.001	-0.001						
				(-0.431)	(-0.314)	(-0.188)						
Drought	-2.09e-05	0.000	0.001**	-3.32e-05	0.000	0.001**	-2.44e-05	0.000	0.002**	-1.59e-05	0.000	0.001**
	(-0.0772)	(0.523)	(2.864)	(-0.119)	(0.501)	(2.818)	(-0.0907)	(0.496)	(2.969)	(-0.0588)	(0.520)	(2.408)
Soy price	1.07e-05	-7.66e-06	0.000	7.37e-06	-1.62e-	0.000	1.46e-05	1.38e-06	0.001	1.42e-05	-1.80e-06	0.000
	(0.0642)	(-0.0406)	(0.787)	(0.0439)	(-0.0849)	(0.834)	(0.0876)	(0.00737)	(1.177)	(0.0846)	(-	(0.287)
Rice price	-0.0001	-0.000	-0.001	-0.000	-0.000	-0.001	-0.000	-0.000	-0.001	-0.000	-0.000	-0.001
	(-0.710)	(-1.562)	(-1.499)	(-0.682)	(-1.511)	(-1.303)	(-0.644)	(-1.536)	(-1.483)	(-0.705)	(-1.570)	(-1.446)
Barley price	0.000*	0.000	0.001	0.000*	0.000	0.001	0.000*	0.000*	0.001	0.000*	0.000*	0.001
	(1.763)	(1.638)	(1.689)	(1.705)	(1.617)	(1.523)	(1.730)	(1.657)	(1.681)	(1.803)	(1.693)	(1.713)
January							-0.000**	-9.56e-	-0.000**			
							(-2.561)	(-2.407)	(-2.698)			
February										-6.20e-05	-4.58e-05	-0.000*
										(-1.373)	(-1.017)	(-1.903)
Constant	0.0033**	0.009***	0.007	0.003***	0.009***	0.006	0.003***	0.008***	0.006	0.003***	0.009***	0.009*
	(4.876)	(6.689)	(1.690)	(4.851)	(6.649)	(1.491)	(4.835)	(6.595)	(1.423)	(4.807)	(6.560)	(1.847)
Observations	485	485	485	484	484	484	485	485	485	485	485	485
R2 overall	0.866	0.864		0.867	0.652		0.868	0.866		0.867	0.653	
R2 between		0.999			0.999			0.999			0.999	
R2 within		0.653			0.652			0.657			0.653	
Number of prefecture		17	17		17	17		17	17		17	17
Number of instruments			16			19			19			19
Hansen statistic			14.67			11.99			15.07			15.15
p value of Hansen statistic			0.145			0.446			0.238			0.234
Arellano-Bond test for			-3.114			-3.239			-3.083			-2.907
p value for AR(1)			0.00185			0.00120			0.00205			0.00365
Arellano-Bond test for			0.634			0.304			0.324			0.537
p value for AR(2)			0.526			0.761			0.746			0.591

Table A2b (continued): Height dispersion models: estimation results with climate data and prefecture fixed effect regressions, dynamic panel

	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM
Dispersion (-1)	0.907***	0.771***	0.869***	0.907***	0.770***	0.782***	0.907***	0.771***	0.846***	0.905***	0.760***	0.900***	0.906***	0.769***	0.793***
	(53.38)	(23.54)	(7.722)	(53.36)	(23.49)	(5.207)	(53.40)	(23.52)	(7.059)	(53.14)	(22.94)	(13.85)	(53.46)	(23.58)	(4.153)
Drought	-2.20e-05	0.000	0.001**	-2.14e-	0.000	0.001**	-2.32e-05	0.000	0.001**	-3.76e-	0.000	0.001*	-9.40e-	6.13e-05	0.001*
	(-0.0811)	(0.520)	(2.207)	(-0.0785)	(0.536)	(2.630)	(-0.0857)	(0.517)	(2.429)	(-0.139)	(0.417)	(1.945)	(-0.344)	(0.211)	(1.919)
Soy price	1.23e-05	-6.32e-	0.000	1.09e-05	-8.46e-	-0.000	1.81e-05	-2.62e-	0.000	-5.81e-	-4.33e-	0.000	-3.59e-	-6.23e-05	-0.000
	(0.0731)	(-0.0334)	(1.054)	(0.0649)	(-0.0448)	(-0.307)	(0.108)	(-0.0139)	(1.064)	(-0.0345)	(-0.229)	(0.468)	(-0.213)	(-0.328)	(-0.757)
Rice price	-0.000	-0.000	-0.001	-0.000	-0.000	-0.001	-0.000	-0.000	-0.001	-0.000	-0.000	-0.000	-4.26e-	-0.000	-0.000
	(-0.714)	(-1.563)	(-1.277)	(-0.708)	(-1.568)	(-1.588)	(-0.723)	(-1.560)	(-1.502)	(-0.626)	(-1.437)	(-1.190)	(-0.244)	(-1.068)	(-0.292)
Barley price	0.000*	0.000	0.001	0.000*	0.000	0.001*	0.000*	0.000	0.001*	0.000*	0.000	0.001*	0.000	0.000	0.000
	(1.758)	(1.633)	(1.545)	(1.757)	(1.644)	(1.909)	(1.732)	(1.609)	(1.753)	(1.709)	(1.498)	(1.785)	(1.565)	(1.417)	(1.108)
March	9.03e-06	7.52e-06	0.000**												
	(0.131)	(0.110)	(2.876)												
April				5.53e-06	-5.13e-	-0.001									
				(0.0192)	(-0.180)	(-0.524)									
May							-0.000	-0.000	-0.002						
							(-0.689)	(-0.408)	(-1.728)						
June										0.000	0.001*	-0.001*			
										(1.020)	(1.752)	(-2.054)			
July													0.001*	0.001*	0.001
													(1.859)	(1.918)	(0.486)
Constant	0.003***	0.009***	0.004	0.003***	0.009***	0.009	0.003***	0.009***	0.006	0.003***	0.009***	0.003	0.003***	0.008***	0.008
	(4.868)	(6.680)	(0.936)	(4.863)	(6.679)	(1.549)	(4.842)	(6.645)	(1.174)	(4.951)	(6.910)	(1.364)	(4.879)	(6.704)	(1.112)
Observations	485	485	485	485	485	485	485	485	485	485	485	485	485	485	485
R2 overall	0.866	0.864		0.866	0.653		0.867	0.653		0.867	0.655		0.867	0.865	
R2 between		0.999			0.999			0.999			0.999			0.999	
R2 within		0.653			0.653			0.653			0.655			0.655	
Number of prefecture		17	17		17	17		17	17		17	17		17	17
Number of instruments			19			19			19			25			19
Hansen statistic			11.67			12.12			14.31			14.01			13.24
p value of Hansen statistic			0.473			0.436			0.281			0.729			0.352
Arellano-Bond test for			-3.305			-2.815			-3.221			-3.150			-2.566
p value for AR(1)			0.001			0.005			0.001			0.001			0.010
Arellano-Bond test for			0.158			0.856			0.997			0.802			0.920
p value for AR(2)			0.874			0.392			0.319			0.422			0.357

Table A2b (continued): Height dispersion models: estimation results with climate data and prefecture fixed effect regressions, dynamic panel

	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM	OLS	WG	SGMM
Disperstion (-1)	0.905***	0.765***	0.835***	0.909***	0.773***	0.822***	0.909***	0.775***	0.842***	0.907***	0.766***	0.838***	0.907***	0.771***	0.851***
	(53.19)	(23.33)	(15.96)	(53.14)	(23.34)	(9.461)	(53.32)	(23.31)	(8.209)	(53.20)	(23.05)	(9.019)	(53.39)	(23.48)	(7.216)
Drought	-6.35e-05	8.41e-05	0.000756	-2.98e-	0.000	0.001***	-1.71e-05	0.000	0.002**	-8.88e-	0.000	0.001**	-2.50e-	0.000	0.001**
	(-0.233)	(0.290)	(1.304)	(-0.110)	(0.506)	(3.371)	(-0.0628)	(0.525)	(2.541)	(-0.0326)	(0.610)	(2.742)	(-0.0920)	(0.511)	(2.673)
Soy price	8.33e-07	-1.81e-05	0.000	-6.11e-	-1.84e-	0.000	1.99e-05	-2.70e-	-7.20e-05	9.17e-06	-8.00e-06	0.001	1.26e-05	-6.19e-06	0.000
	(0.00497	(-0.0962)	(0.475)	(-0.0363)	(-0.0966)	(0.787)	(0.118)	(-0.0143)	(-0.161)	(0.0546)	(-0.0424)	(1.243)	(0.0752)	(-0.0328)	(0.392)
Rice price	-0.000	-0.000	-0.001**	-0.000	-0.000	-0.001	-0.000	-0.000	-0.001	-0.0001	-0.000	-0.001*	-0.000	-0.000	-0.001
	(-0.609)	(-1.485)	(-2.406)	(-0.715)	(-1.543)	(-1.442)	(-0.690)	(-1.529)	(-1.375)	(-0.706)	(-1.618)	(-1.850)	(-0.719)	(-1.563)	(-1.234)
Barley price	0.000*	0.000*	0.001**	0.000*	0.000*	0.001	0.000	0.000	0.0011	0.000*	0.000*	0.001**	0.000*	0.000	0.001
	(1.781)	(1.663)	(2.309)	(1.798)	(1.652)	(1.676)	(1.634)	(1.570)	(1.668)	(1.760)	(1.720)	(2.293)	(1.756)	(1.637)	(1.580)
August	0.001	0.001*	0.004*												
	(1.320)	(1.695)	(1.892)												
September				-0.000	-0.000	-0.000									
				(-0.977)	(-0.474)	(-0.395)									
October							-0.001	-0.000	0.002						
							(-1.403)	(-0.698)	(1.511)						
November										1.07e-05	0.000	-0.000			
										(0.0709)	(0.906)	(-0.408)			
December													-3.55e-	-1.61e-05	0.000
													(-0.631)	(-0.288)	(1.638)
Constant	0.003***	0.009***	0.007***	0.003***	0.009***	0.006*	0.003***	0.008***	0.006	0.003***	0.009***	0.006	0.003***	0.009***	0.006
	(4.940)	(6.817)	(3.133)	(4.792)	(6.573)	(1.985)	(4.713)	(6.456)	(1.729)	(4.860)	(6.728)	(1.628)	(4.851)	(6.640)	(1.271)
Observations	485	485	485	485	485	485	484	484	484	484	484	484	485	485	485
R2 overall	0.867	0.655		0.867	0.653		0.867	0.864		0.866	0.863		0.867	0.864	
R2 between		0.999			0.999			0.999			0.999			0.999	
R2 within		0.653			0.653			0.653			0.655			0.655	
Number of prefecture		17	17		17	17		17	17		17	17		17	17
Number of instruments			25			19			19			19			19
Hansen statistic			10.39			14.35			10.24			12.66			12.83
p value of Hansen statistic			0.919			0.279			0.595			0.394			0.381
Arellano-Bond test for AR(1)			-3.046			-3.129			-3.170			-3.263			-3.326
p value for AR(1)			0.002			0.003			0.001			0.001			0.001
Arellano-Bond test for AR(2)			-0.032			0.629			0.502			0.301			0.379
p value for AR(2)			0.975			0.529			0.616			0.763			0.705

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