Demographic, Residential, and Socioeconomic Effects on the Distribution of 19th Century US White Statures

SCOTT ALAN CARSON

CESIFO WORKING PAPER NO. 2563
CATEGORY 3: SOCIAL PROTECTION
FEBRUARY 2009

CESifo *Working Paper No. 2563*

Demographic, Residential, and Socioeconomic Effects on the Distribution of 19th Century US White Statures

Abstract

Using a source of 19th century US state prison records, this study addresses European-American stature variation. The most commonly cited sources for stature variation are diets, disease, and work effort. However, vitamin D is also vital in human statures and health. This paper demonstrates that 19th century white statures were positively associated with direct sunlight, which is the primary source of vitamin D in mammals. Stature and insolation are associated with occupations, and workers who spent more time outdoors produced more vitamin D and grew taller. White statures also decreased throughout the 19th century, and this stature diminution is observed across the stature distribution.

JEL Code: I30, I31, J00, J15.

Keywords: 19th US white statures, vitamin D, solar radiation, quantile regression.

Scott Alan Carson
School of Business
University of Texas, Permian Basin
4901 East University
Odessa, TX 79762
USA
carson_s@utpb.edu

Please do not cite without permission from the author.
I appreciate comments from Marco Sünder, and John Komlos. Owen Wallace-Servera, Sandy Triepke and Anita Voorhies provided excellent research assistance. All errors are mine.

Demographic, Residential, and Socioeconomic Effects on the Distribution of 19th Century United States White Stature

I. Introduction

The use of height data to measure living standards is now a well-established method in economics (Fogel, 1994, p. 138). A populations' average stature reflects the cumulative interaction between nutrition, disease exposure, work, and the physical environment (Steckel, 1979, pp. 365-367). By considering average versus individual stature, genetic differences are mitigated, leaving only the influences of the economic and physical environments on stature. When diets, health, and physical environments improve, average stature increases and decreases when diets become less nutritious, disease environments deteriorate, or the physical environment places more stress on the body. Therefore, stature provides considerable insights into understanding historical processes and augments other welfare measures for 19th century European-Americans. Using a new source of 19th century United States prison records and robust statistics, the present study contrasts the heights of US white males across the stature distribution and adds a new explanation for traditional sources of white stature variation.

An inadequately explored source for 19th century stature variation may be related to biology, especially its relation to geography. Calcium and vitamin D are two chemical elements required throughout life for healthy bone and teeth formation; however, their abundance are most critical during younger ages (Wardlaw, Hampl, and Divilestro, 2004, pp. 394-396; Tortolani et al, 2002, p. 60). Calcium generally comes from dairy products, and vitamin D in not dietary but is produced by the synthesis of cholesterol and sunlight in the epidermises'' stratum granulosum (Holick, 2004a, pp. 363-364; Nesby-O'dell, 2002, p. 187; Loomis, 1967, p. 501; Norman, 1998, p. 1108; Holick, 2007). Greater direct sunlight (insolation) produces more vitamin D, and vitamin D is related to adult terminal statures (Xiong et al, 2005, pp. 228, 230-231; X-ZLiu et al, 2003; Ginsburg et al 1998; Uitterlinden et al, 2004).

After the circulatory system contains sufficient amounts of vitamin D and to avoid vitamin D toxicity, vitamin D production is restricted within the stratum granulosum and residual vitamin D is broken down into inert matter (Holick et al, 1981, pp. 591-592; Jablonski, 2006, p. 62; Holick, 2001, p. 20; Holick, 2004a, p. 363). This self-limiting vitamin D effect may account for white stature variation with insolation, because at North American latitudes whites are close to the natural threshold where vitamin D production is curtailed. Moreover, to firmly establish the link between stature, insolation, and vitamin D, it is necessary to demonstrate the significance of the stature-insolation relationship across different samples and across their stature distributions. At the opposite extreme, insufficient vitamin D has been linked to rickets, osteomalasia, auto-immune diseases, and certain cancers (Holick, 2001, p. 28; Garland et al, 2006, pp. 252-256; Grant et al, 2003, p. 372).

It is against this backdrop that using robust statistics this paper addresses three paths of inquiry into 19^{th} century white stature variation in the US. First, how were insolation and vitamin D production related to white statures across the white stature distribution? This study finds that white statures were positively related with insolation and increased with insolation at a decreasing a rate. Second, how did white statures vary with occupations? White farmers were taller than workers in other occupations, and this farmer stature advantage is generally attributed to better nutrition and rural environments. However, this paper offers an additional explanation for the farmer stature advantage. Third, how did white statures vary throughout the 19th century? Results presented here illustrate that 19th century US white statures decreased throughout the 19th century, which is observed equally across the stature distribution.

II. Data

Prison Records

Table 1, Nineteenth Century US White Populations is State Prisons

Prisons	*N*	*Percent*	*Prisons*	*N*	*Percent*
Arizona	2,171	1.73	Kentucky	6,650	5.31
California	8,230	6.57	Missouri	23,787	19.00
Colorado	7,021	5.61	New Mexico	1,998	1.60
Georgia	157	.13	Ohio	24,841	19.84
Idaho	2,074	1.66	Oregon	2,040	1.63
Illinois	9,942	7.94	Pennsylvania	16,026	12.80
Kansas	4,082	3.26	Texas	16,171	12.92

Source: Data used to study black and white anthropometrics is a subset of a much larger 19th century prison sample. All available records from American state repositories have been acquired and entered into a master file. These records include Arizona, California, Colorado, Idaho, Illinois, Kansas, Kentucky, Missouri, New Mexico, Ohio, Oregon, Pennsylvania, Texas, Utah and Washington.

Notes: Stature is in centimeters. The occupation classification scheme is consistent with Ferrie (1997).

The data used here to study white statures is part of a large 19th century prison sample. All state prison repositories were contacted and available records were acquired and entered into a master data set. These prison records include Arizona, California, Colorado, Idaho, Illinois, Kansas, Kentucky, Missouri, New Mexico, Ohio, Oregon, Pennsylvania, Texas, and Washington (Table 1). Most whites in the sample were incarcerated in Ohio, Missouri, Texas, and Pennsylvania prisons.

All historical height data have various biases, and prison and military records are the most common sources for historical stature data. One common shortfall for military samples is a truncation bias imposed by minimum stature requirements (Fogel et al, 1978, p. 85; Sokoloff and Vilaflor, 1982, p. 457, Figure 1; A'Hearn, 2004). Fortunately, prison records do not implicitly suffer from such a constraint and the subsequent truncation bias observed in military samples. However, prison records are not above scrutiny. The prison data may have selected many of the materially poorest individuals who were drawn from lower socioeconomic groups, that segment of society most vulnerable to economic change (Bogin, 1991, p. 288; Komlos and Baten, 2004, p. 199; Nicholas and Steckel, 1991, p. 944). For height as an indicator of biological variation, this kind of selection is preferable to that which marks many military records – minimum height requirements for service (Fogel, 1978, p. 85; Sokoloff and Vilaflor, 1982, p. 457, Figure 1). Moreover, if—at the margins of subsistence—demographic, socioeconomic factors, and insolation were significant in stature variation, prison records may more clearly illustrate these effects.

There also is concern over entry requirements, and physical descriptions were recorded by prison enumerators at the time of incarceration as a means of identification and reflect pre-incarceration conditions. Between 1830 and 1920, prison officials routinely recorded the dates inmates were received, age, complexion, nativity, stature, pre-incarceration occupation, and crime. All records with complete age, stature, occupation, and nativity were collected. There was great care recording inmate statures because accurate measurement had legal implications for identification in the event that inmates escaped and were later recaptured.[1] Arrests and prosecutions across states may have resulted in various selection biases that may affect the results of this analysis. However, white stature variation within US prisons is consistent with other stature studies (Steckel, 1979; Margo and Steckel, 1982; Nicholas and Steckel, 1991, pp. 941-943; Komlos, 1992; Komlos and Coclanis, 1997; Bodenhorn, 1999; Sünder, 2004).

Fortunately, inmate enumerators were quite thorough when recording inmate complexion and occupation. For example, enumerators recorded white complexions as light, medium, dark, and fair. The white inmate complexion classification is further supported by European immigrant complexions, which were always of fair complexion and were also recorded in US prisons as light, medium, dark, and fair.[2] Enumerators recorded a broad continuum of occupations and defined them narrowly, recording over 200 different occupations, which are classified here into four categories: merchants and high skilled workers are classified as white-collar workers; light manufacturing, craft workers, and carpenters are classified as skilled workers; workers in the agricultural

[1] Many inmate statures were recorded at quarter, eighth, and even sixteenth increments.

[2] I am currently collecting 19th century Irish prison records. Irish prison enumerators also used light, medium, dark, fresh and sallow to describe white prisoners in Irish prisons from a traditionally white population. To date, no inmate in an Irish prison has been recorded with a complexion consistent with African heritage.

sector are classified as farmers; laborers and miners are classified as unskilled workers (Tanner, 1977, p. 346; Ladurie, 1979; Margo and Steckel, 1992; p. 520). Unfortunately, inmate enumerators did not distinguish between farm and common laborers. Since common laborers probably encountered less favorable biological conditions during childhood and adolescence, this potentially overestimates the biological benefits of being a common laborer and underestimates the advantages of being a farm laborer. Because the purpose of this study is to compare 19th century white male statures, blacks and immigrants are excluded from the analysis.

Because the youth height distribution is itself a function of the age distribution, a youth height index is constructed that standardizes for age to determine youth stature normality and whether there were arbitrary truncation points imposed on inmate stature, either by law enforcement or state legislation. This index is calculated by first calculating the average stature for each age group; each observation is then divided by the average stature for the relevant age group (Komlos, 1987, p. 899). Figure 1 demonstrates that white statures were distributed approximately normal and there is no evidence of age heaping or arbitrary truncation points.

Table 2, Descriptive Statistics of Whites in National Prison Data

Ages	*N*	*Percent*	*Height (cms)*	*S.D. (cms)*
Teens	16,924	13.52	169.75	6.70
20s	64,187	51.27	171.95	6.52
30s	27,181	21.71	171.99	6.48
40s	10,987	8.78	171.89	6.50
50s	4,360	3.48	171.61	6.51
60s	1,318	1.05	171.25	6.73
70s	233	.19	170.94	6.42
Birth Decade				
1800	906	.72	172.41	6.50
1810	2,467	1.97	172.52	6.56
1820	4,202	3.36	172.45	6.80
1830	7,995	6.39	171.79	6.66
1840	16,541	13.21	171.46	6.52
1850	25,084	20.04	171.31	6.69
1860	25,436	20.32	171.69	6.55
1870	22,334	17.84	171.65	6.52
1880	13,075	10.44	171.69	6.50
1890	6,744	5.39	171.90	6.51
1900	406	.32	170.67	6.30
Occupations				
White-Collar	13,800	11.02	171.32	6.37
Skilled	32,196	25.72	171.28	6.38
Farmers	16,640	13.29	173.16	6.44
Unskilled	56,344	45.01	171.54	6.66
No Occupations	6,210	4.96	170.97	7.14
Nativity				
Northeast	4,030	3.22	170.70	6.31
Middle Atlantic	32,335	25.83	170.09	6.36
Great Lakes	32,629	26.06	171.88	6.42
Plains	17,839	14.25	171.94	6.38
Southeast	21,857	17.46	172.91	6.66
Southwest	10,708	8.55	173.39	6.84
Far West	5,792	4.63	170.62	6.60
Decade Received				
1820s	13	.01	168.52	5.29
1830s	958	.77	171.56	6.47
1840s	1,859	1.48	171.80	7.08
1850s	3,683	2.94	172.4	6.69
1860s	9,637	7.70	170.99	6.68
1870s	20,557	16.42	171.48	6.73
1880s	22,108	17.66	171.70	6.66
1890s	18,691	22.92	171.70	6.46
1900s	19,889	15.89	171.50	6.50

1910s	17,325	13.84	171.96	6.42
1920s	470	.38	172.38	6.45

Source: See table 1.

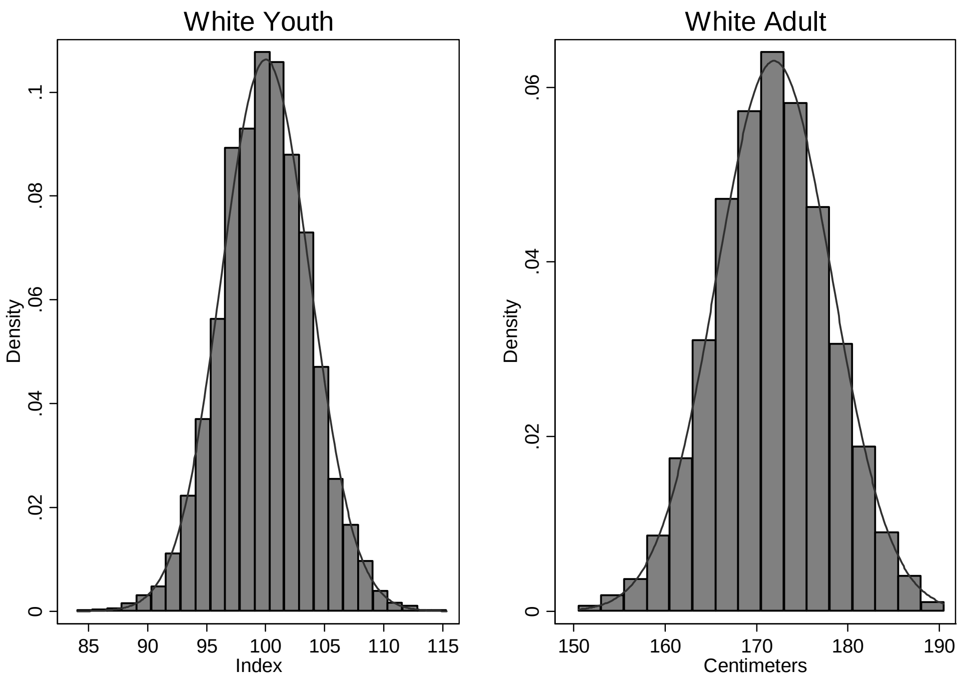

Figure 1, Nineteenth Century US White Stature Distributions

Source: See Table 1.

Table 2 presents proportions for white inmates' age, birth decade, occupations, and nativity. Although average statures are included, they are not reliable because of possible compositional effects, which are accounted for in the regression models that follow. Age percentages demonstrate that whites were incarcerated at older ages. Most prisoners were born in the mid-19th century; occupations reflect socioeconomic status, and while prison inmates typically come from lower working classes, there was a sizeable share of inmates from white-collar and skilled occupations. Most whites in the sample were born in the Middle-Atlantic and Great Lakes states; the South and Far-west are also represented in the sample.

United States' Insolation

To account for the relationship between vitamin D and stature, a measure is constructed that accounts for solar radiation. Insolation is the incoming direct sunlight that reaches the earth, its atmosphere, and surface objects.[3] Insolation is also the primary source of vitamin D (Holick, 1991, p. 590; Holick, 2007, p. 270). Because of its distance from the equator, Europeans were efficient in vitamin D production at low insolation latitudes in the Northern hemisphere. As early hominids migrated out of African to Northern latitudes, they received less solar radiation, and through the process of natural selection, darker pigmented hominids were less successful hunter-gatherers in Northern latitudes and were selected-out (Loomis, 1967, pp. 503-504).

---

[3] Insolation is an acronym for incident solar radiation, and is a measure for sunlight energy received for a given surface area at a given time. If w equals watts, m equals meters, and i equals insolation,

$$i = \frac{w}{m^2} = \frac{kwh}{m^2 \cdot day}.$$

Because US historical insolation is unavailable, a modern insolation index (1993-2003) is constructed, and monthly insolation values are measured from January through June. The insolation index measures statewide average insolation levels across each of the states based on the hours of direct sunlight received per day at county centroids in each state.[4] Each state estimate is then determined by summing the average hours of direct sunlight for each county (at its centroid), weighted by the proportion of the county's total land area (in square miles) to the state's total land area (in square miles). While this index is a rough approximation for historical insolation, it provides sufficient detail to capture state latitudinal insolation variation and consequently, vitamin D production. Predictably, Southern states have greater insolation than Northern states. For example, Texas receives 1.43, or 29 percent, more hours of direct sunlight per day than New York. It is also difficult to interpret insolation's net direct effect on human health, because greater insolation reduces calories required to maintain body temperature and produces more vitamin D, but greater insolation also warms surface temperatures, which may have made disease environments less healthy from water-borne diseases, especially in the South.

III. Socioeconomic Status, Geography, Insolation, and White Stature

Nineteenth century white statures were related to age, socioeconomic status, birth cohorts, and nativity; they may have also been related to insolation and vitamin D production. Which of these factors dominates reveals much about conditions facing 19th

[4] Insolation is not the insolation in the county that surrounds the state's centroid, but insolation in each county's geographic center. The range of state insolation values extends from Maine's minimum of 3.43 hours of direct sunlight to Arizona's maximum of 5.22 hours of direct sunlight per day.

century whites. If US white nativity was a source for stature variation, regional diets and social practices were a possible driving force in stature variation. If occupations were associated with stature, relative social position was a primary impetus driving white stature variation. If, however, insolation was a significant impetus on white stature, part of 19th century white stature variation was not due to social or cultural factors but also geographical, and whites born in the South would have benefited from extended exposure to insolation.

To better understand the interaction between the conditional stature distribution and socioeconomic and demographic characteristics, a stature quantile regression function is constructed. Let s_i represent the stature of the i^{th} inmate and x_i the vector of covariates for birth cohort, socioeconomic status, and demographic characteristics. The conditional quantile function is

$$s_i = Q_y\left(p \middle| x\right) = \theta x + \eta S(p),\ p \in (0,1)$$

which is the p^{th}-quantile of s, given x.[5] The interpretation of the coefficient θ_i is the influence of the i^{th} covariate on the stature distribution at the p^{th} quantile. For example, the age coefficient at the median (.5 quantile) is the stature increase that keeps an "average" inmate's stature on the median if age increases by one year. When estimating stature regressions, quantile estimation offers several advantages over least squares. Two advantages in anthropometric research are more robust estimation in the face of an unknown truncation point and greater description of covariate effects across that stature distribution.

---

[5] The coefficient vector θ is obtained using techniques presented in Koenker and Bassett (1978 and 1982) and Hendricks and Koenker (1992).

We test which variables were associated with the height of 19th century whites. To start, stature for the ith individual is related to age, socioeconomic status, birth period, nativity, and insolation.

$$Cent_i = \alpha + \beta_1^p Black_i + \sum_{a=12}^{70} \beta_a^p Age_i + \sum_{t=1}^{10} \beta_t^p Birth\,Decade_i + \sum_{l=1}^{3} \beta_l^p Occupation_i$$

$$+ \sum_{n=1}^{6} \beta_n^p Nativity_i + \beta_{Migration}^p Migration_i + \sum_{d=1}^{4} \beta_d^p Move\,Direction_i + \beta_{Insol}^p Insolation_i$$

$$+ \beta_{Insol^2}^p Insolatiion_i^2 + \varepsilon_i^p$$

Dummy variables are included for individual youth ages 12 through 22; adult age dummies are included for ten year age intervals from the 40s through the 70s. Birth decade dummies are in ten year intervals from 1800 through 1899. Occupation dummy variables are for white-collar, skilled, farmers, and unskilled occupations. Nativity dummy variables are included for birth in Northeast, Middle Atlantic, Great Lakes, Southeast, Southwest, and Far West regions. A dummy variable accounts for migration status and directional migration dummy variables are included to account for North-South migrations.[6] If insolation was a driving force in stature growth, northward moves

---

[6] North1 is an intermediate move from Southern to Central or Central to Northern states. North2 is a long distance move from Southern to Northern states. South1 is a move from a Northern to Central or Central to Southern state. South2 is a move from Northern to Southern states. Northern states include Maine, Vermont, New Hampshire, Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Michigan, Wisconsin, Iowa, Minnesota, North Dakota, South Dakota, Wyoming, Montana, Idaho, Oregon, and Washington. Central states include Delaware, Maryland, Virginia, Wes Virginia, Kentucky, Indiana, Illinois, Missouri, Nebraska, Kansas, Colorado, Utah, Nevada, and California. Southern states include North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, Texas, New Mexico, and Arizona. The binary variable North1

will have adverse stature effects, and southward moves will be associated with taller statures. Continuous insolation and insolation difference variables between receiving and sending locations are added to account for insolation and vitamin D production.

Table 3's model 1 presents least squares estimates for the white sample. To illustrate how white stature was related to demographic, occupation, nativity, migration, and insolation across the stature distribution, models 2 through 6 present .25, .50, .75, .90, and .95 quantile stature estimates.

---

is an intermediate move from Southern to Central or Central to Northern states. North2 is a long distance move from Southern to Northern states. South1 is a move from a Northern to Central or Central to Southern state. South2 is a move from Northern to Southern states.

Table 3, Nineteenth Century United States National Quantile Stature Models related to Demographics, Birth Period, Migration, and Insolation by Socioeconomic Status

	Model 1	*Model 2*	*Model 3*	*Model 4*	*Model 5*	*Model 6*
	OLS	*.25*	*.50*	*.75*	*.90*	*.95*
Intercept	143.43***	135.27***	143.74***	153.24***	155.80***	169.44***
Ages						
12	-17.35***	-21.16***	-16.48***	-13.80***	-10.30***	-10.02***
13	-15.26***	-17.99***	-15.85***	-10.37***	-8.79***	-6.83***
14	-13.27***	-13.42***	-13.45***	-12.49***	-11.77***	-10.15***
15	-8.31***	-8.50***	-8.35***	-8.04***	-6.81***	-5.88***
16	-4.90***	-4.80***	-5.04***	-5.09***	-5.35***	-5.50***
17	-3.13***	-2.86***	-3.08***	-3.29***	-3.14***	-3.46***
18	-2.00***	-1.81***	-2.11***	-2.28***	-2.30***	-2.21***
19	-1.06***	-.916***	-1.04***	-1.23***	-1.36***	-1.39***
20	-.586***	-.596***	-.528*	-.606***	-.778***	-.651**
21	-.146***	-.088	-.141*	-.160*	-.169*	-.231*
22	-.001**	.021	-.005	.043	-.001	.158
23-39	Reference	Reference	Reference	Reference	Reference	Reference
40s	-.333***	-.228***	-.444***	-.486***	-.214*	-.334***
50s	-.842***	-.786***	-.864***	-.843***	-.711***	-.778***
60s	-1.43***	-1.68***	-1.66***	-1.28***	-1.36***	-858**
70s	-2.03***	-1.97***	-2.28***	-2.07***	-1.98***	-.904*
Birth Decade						
1800s	1.52***	1.66***	1.76***	1.76***	1.02***	.836
1810s	1.43***	1.73***	1.46***	1.50***	1.14***	1.04**
1820s	1.13***	1.03***	1.12***	.328***	1.32***	1.58***
1830s	.287***	.259*	.216**	.328**	.321*	.379**
1840s	-.124**	-.085	-.186***	-.195***	-.169	-3.9^{-7}
1850s	-.317***	-.368***	-.294***	-.309	-.350***	-.184*
1860s	Reference	Reference	Reference	Reference	Reference	Reference
1870s	-.260***	-.085	-.405***	-.309***	-.299***	-.221***
1880s	-.584***	-.364***	-.714**	-.681***	-.661***	-.680***
1890s	-.411***	-.330**	-.510***	-.222*	-.366**	-.333
1900s	-.170	-.175	-.206	.010	-.732***	-.935**
Occupations						
White-Collar	-.178***	-.053	-.184**	-.263***	-.450***	-.356***
Skilled	-.192***	-.053	-.195***	-.264***	-.407***	-.405***
Farmer	1.21***	1.31***	1.15***	1.17***	.997***	.953***
Unskilled	Reference	Reference	Reference	Reference	Reference	Reference
Nativity						
Northeast	-1.46***	-1.21***	-1.61***	-1.49***	-1.73***	-2.12***

Middle Atlantic	-1.78***	-1.61***	-1.88***	-1.87***	-1.89***	-2.36***
Great Lakes	-.095	.066	-.207***	-.145***	8.7^{-4}***	-.249***
Plains	Reference	Reference	Reference	Reference	Reference	Reference
Southeast	.954***	.881***	.930***	1.10**	1.12***	.850***
Southwest	2.87***	2.78***	2.93***	2.84***	3.23***	3.19***
Far west	.193	.329*	.224	.051	.028	-.202
Migration Status						
Migrant	.284***	.194***	.266***	.392***	.314***	.292***
Non-migrant	Reference	Reference	Reference	Reference	Reference	Reference
Move Direction						
North1	-.733***	-.609***	-.689***	-.830***	-.785***	-.615***
North2	-.333*	-.137	-.320***	-.542***	-.498*	-.087
South1	.221***	.124	.235***	.302***	.190***	.318*
South2	.734***	.379	.606***	1.08***	1.29***	1.76***
Insolation Variables						
Insolation	14.23***	15.96***	14.26***	11.43***	12.08***	6.91**
$Insolation^2$	-1.75***	-1.94***	-1.77***	-1.40***	-1.48***	-.891**
Insolation Difference	.322***	.563***	.260***	.155**	.168*	-2.6^{-7}
N	125,190	125,190	125,190	125,190	125,190	125,190
R^2	.0677	.0328	.0345	.0345	.0340	.0340

Source: See Table 1.

Notes: *-1 percent significant; **-5 percent significant; ***-10 percent significant.

Standard errors attained with bootstrap.

Three general patterns emerge when assessing 19th century white statures. First, consistent with the bio-medical explanation, for each additional hour of direct sunlight, whites reached about one centimeter taller statures (Holick et at, 1981, pp. 590-591; Jablonski, 2006, p. 62; Holick, 2004a, p. 363; Holick, 2004b, p. 1680S; Carson, EEH, forthcoming). Moreover, white statures increased with insolation at a decreasing rate, indicating there is a natural threshold to the amount of vitamin D produced internally, and whites in North American latitudes were at the threshold where vitamin D production is curtailed (Holick et al, 1981, pp. 590-591; Jablanski, 2006, p. 62; Holick, 2004a, p. 363; Holick, 2004b, p. 1680S). Tests for insolation's affect across the stature distribution demonstrate that the amount of sunlight was positively associated with stature, and whites in lower stature quantiles received larger stature returns from insolation than whites in higher stature quantiles (Koenker, 2005, pp. 75-76; Koenker and Bassett 1982). Furthermore, the positive coefficient on the insolation difference variable between sending and receiving locations indicates that for each additional hour of sunlight associated with a migration, white migrants were about one-half cms taller than non-migrants. Therefore, insolation and vitamin D probably influenced 19th century white statures, which is supported by modern population studies (Norman, 1998, pp. 1108-1110; Holick, 1995, pp. 641s-642s; Nesby-O'Dell et al, 2002, p. 189).

Second, white statures varied by socioeconomic status, and farmers in the prison sample were consistently taller than workers in other occupations (Metzer, 1975, p. 134; Margo and Steckel, 1982, p. 525; Steckel, 1979, p. 373). Moreover, tests for occupational affects illustrate that farmers in lower quantiles received greater stature returns from insolation than workers in higher stature quantiles. Farmers traditionally had greater access to superior diets and nutrition, but farmers also worked outdoors and were exposed to more sunlight during adolescent ages; consequently, stature and socioeconomic status may also be related to vitamin D production (Bodiwala et al, 2003, pp. 659-660; Tangpricha et al, 2002, p. 662). Islam et al (2007, pp. 383-388) demonstrate that children exposed to more insolation produce more vitamin D, and if there was little movement away from parental occupations, 19th century occupations may also be a good indicator for the occupational environment in which individuals come to maturity (Costa, 1993, p. 367; Margo and Steckel, 1992, p. 520; Wananamethee et al, 1996, pp. 1256-1262; Nyström-Peck and Lundberg, 1995, pp.734-737). That unskilled workers were also tall suggests that many unskilled workers were agricultural workers, who received sufficient nutrition allocations and almost certainly worked outdoors, received more insolation and produced sufficient vitamin D to reach taller statures.

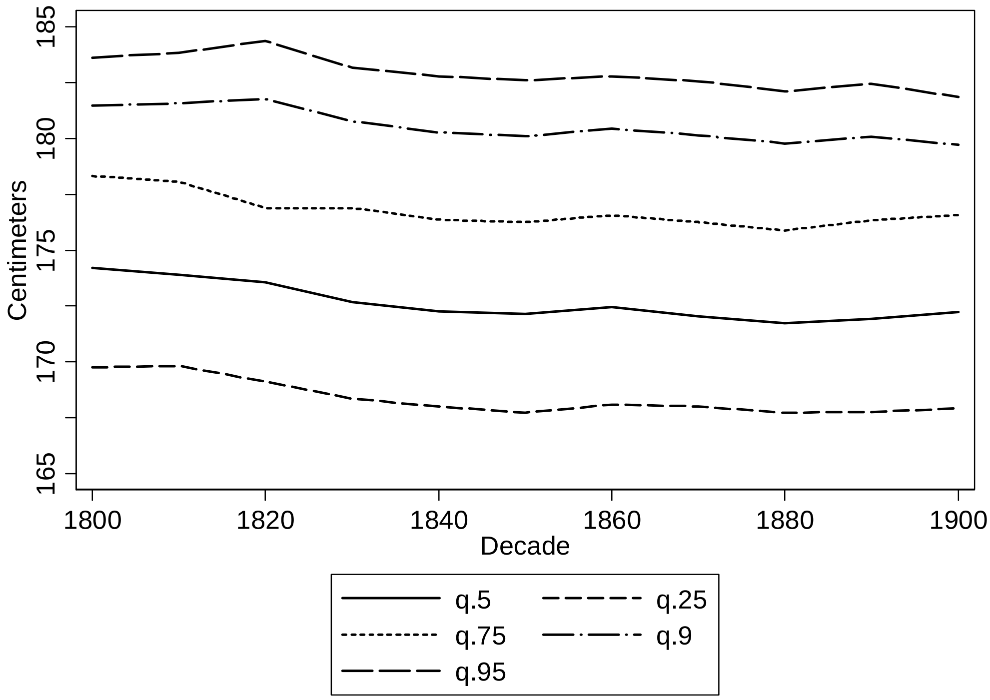

Figure 2, Nineteenth Century US Whites across Quantiles

Source: See Table 3.

Third, white statures decreased throughout the 19th century, and this is observed across the stature distribution. Between 1800 and 1900 and across quantiles, statures declined by nearly 2 cms (Figure 2). Part of the stature decline corresponded with US industrialization and urbanization. Nineteenth century US agricultural commercialization separated producers from consumers. During the early 19th century, white farmers worked in rural agricultural environments, and the rise of Northeastern urban centers—such as New York City, Boston, and Philadelphia—placed disproportionate stress on rural farmers who lived near urban centers (Carson, 2008b, pp. 367-368). For example, although Southeastern Pennsylvanian's were in close physical proximity to leading

Bucks, Chester, and Lancaster counties, they were also closer to urbanized Philadelphia, and Southeastern Pennsylvanian's reached shorter terminal statures than individuals from rural Pennsylvania (Carson, 2008b, pp. 363-368; Cuff, 2005, pp. 154-161). Urbanization and industrialization created other costs related with agricultural commercialization. Industrialization's proliferation compromised the quality of dairy and meat production, and in this pre-refrigeration period, food spoilage increased as the distance between rural farms and urban centers increased (Craig et al., 2004).

Other relationships are consistent with expectations. Statures varied regionally, and Southwestern whites reached the tallest statures. Internal immigrants who located southward were taller than those who immigrated northward, and Southern white stature gains were larger than those experienced by Northern whites. Part of the Southern migration advantage was related to Southern agriculture. The 19th century opening of the South to agriculture increased Southwestern agricultural productivity, which was higher than elsewhere in the US (Higgs, 1977, p. 24; Margo and Steckel, 1982, p. 519; Komlos and Coclanis, 1997, p. 443). Before the Civil War, the South was self-sufficient in food production, and relatively high white wages may have also influenced white Southern statures (Fogel, 1994, pp. 89, 132-133). After the Civil War, Southern wages in the West South Central were in general lower than Midwest wages and were comparable to those in the Middle Atlantic region. Northeasterners, especially youth, encountered adverse biological environments, and contemporary reports of rickets—a result of vitamin D deficiency—may have contributed to shorter Northeastern statures.

IV. Conclusions

This paper demonstrates that insolation was an important source of 19th century white stature variation and illustrates that whites at North American latitudes were closer to the biological threshold were vitamin D production is curtailed. Moreover, to establish the link between stature, insolation, and vitamin D, a positive and significant relationship between insolation and stature is observed across the stature distribution. The stature-insolation hypothesis also adds to our knowledge for why 19th century farmers were taller than workers in other occupations. Farmers were closer to nutritious food supplies and further from urban locations, where disease was most easily spread. However, farmers also worked outdoors, were exposed to more sunlight, produced more vitamin D than their white-collar and skilled counterparts, and reached taller terminal statures. White statures declined throughout the 19th century, a pattern frequently observed with industrialization and urbanization. Therefore, 19th century statures were associated with a complex set of demographic, environmental, and occupational factors, which were consistently related with US white statures across the stature distribution.

References

A'Hearn, Brian "A Restricted Maximum Likelihood Estimator for Truncated Height Samples," *Economics and Human Biology* 2, no. 1 (2004): 5-20.

Bodenhorn, Howard. "A Troublesome Caste: Height and Nutrition of Antebellum Virginia's Rural Free Blacks." *Journal of Economic History.* 59, no. 4 (December, 1999): 972-996.

Bodiwala, Dhaval, Christopher Luscombe, Samson Liu, Mark Saxby, Michael French, Peter Jones, Anthony Fryer and Richard Strange. 2003, "Prostate Cancer Risk and Exposure to Ultraviolet Radiation: Further Support of the Protective Effect of Sunlight," *Cancer Letters v. 192,* pp. 145-146.

Bogin, Barry, 1991, "Measurement of Growth Variability and Environmental Quality in Guatemalan Children," *Annals of Human Biology 18,* pp. 285-294.

Carson, Scott Alan (forthcoming). "Geography, Insolation, and Vitamin D in 19th Century US African-American and White Statures," *Explorations in Economic History.*

Carson, Scott Alan. (2008a) "The Effect of Geography and Vitamin D on African-American Stature in the Nineteenth Century: Evidence from Prison Records," *Journal of Economic History.* 68(3), pp. 812-831.

Carson, SA (2008b) "Health During Industrialization: Evidence from the Nineteenth-Century Pennsylvania State Prison System," *Social Science History* 32(3), pp. 347-372.

Costa, Dora, 1993, "Height, Wealth and Disease among the Native-Born in the Rural Antebellum North," *Social Science History Association,* 17(3), pp. 355-383.

Craig, Lee A., Barry Goodwin, and Thomas Grennes. 2004. "The Effect of Mechanical Refrigeration on Nutrition in the U. S." *Social Science History.* 28(2): 325-336.

Cuff T (1992) A Weighty Issue Revisited: New Evidence on Commercial Swine Weights and Pork Production in Mid-Nineteenth Century America. Agricultural History 66(4): 55-74

Fogel, Robert, Stanley Engerman, James Trussell, Roderick Floud, Clayne Pope, and Larry Wimmer, "Economics of Mortality in North America, 1650-1910: A Description of a Research Project," *Historical Methods,* 11(2), 1978, pp. 75-108.

Fogel, Robert W. "Economic Growth, Population Theory and Physiology: The Bearing of Long-Term Processes on the Making of Economic Policy," *American Economic Review 84(3)*, 1994, pp. 369-395.

Garland, Cedric F, Frank Garland, Edward Gorhom, Margin Lipkin, Harold Newmark, Sharif Mohr, and Michael Holick. (2006) "The Role of Vitamin D in Cancer Prevention." *American Journal of Public Health.* 96(2). pp. 252-261.

Ginsburg, E, G. Livshits, K. Yakovenko and E. Kobyliansky, "Major Gene Control of Human Body Height, Weight and BMI in Five Ethnically Different Populations," *Annals of Human Genetics,* 62, 1998, pp. 307-322.

Grant, William (2003) "Ecological Studies of Solar UV-B Radiation and Cancer Mortality Rates," *Resent Results in Cancer Research*. 164, pp. 371-377.

Higgs, Robert. *Competition and Coercion.* Chicago: University of Chicago Press, 1977.

Holick, Michael F., A. MacLaughlin, and S. H. Doppelt (1981) "Regulation of Cutaneous Previtamin D_3 Photosynthesis in Men: Skin Pigment is not an Essential Regulator." *Science,* 211(6), pp. 590-593.

Holick, Michael F., “Environmental Factors that Influence the Cutaneous Production of Vitamin D.” *American Journal of Clinical Nutrition 61,* 1995, pp. 638S-645S.

Holick, Michael F., (2001) “A Perspective on the Beneficial Effects of Moderate Exposure to Sunlight: Bone Health, Cancer Prevention, Mental Health and Well Being,” Ed. Giacomoni, Paolo, *Sun Protection in Man.* Elsevier: Amersterdam.

Holick, Michael F, “Vitamin D: Importance in the Prevention of Cancers, Type 1 Diabetes, Heart Disease and Osteroporosis.” *American Journal of Clinical Nutrition 79.* 2004a. pp. 362-371.

Holick, Michael, 2004b, “Sunlight and Vitamin D for Bone Health and Prevention of Autoimmune Diseases, Cancers, and Cardiovascular Diseases,” *American Journal of Clinical Nutrition*, supplement, pp. 1678S-1688S.

Holick, Michael F, 2007 “Vitamin D Deficiency.” *New England Journal of Medicine 357(3).* pp. 266-281.

Islam, Talat, W. James Gauderman, Wendy Cozen, Thomas Mack, 2007, “Childhood Sun Exposure Influences Rick of Multiple Sclerosis in Monozygotic Twins,” *Neurology* 69, pp. 381-388.

Jablonski, Nina (2006) *Skin: A Natural History.* Berkeley: University of California Press.

Koenker, Roger, “Robust Methods in Econometrics,” *Econometric Reviews*, (1), 213-215.

Koenker, Roger and G Bassett (1978) “Regression Quantiles,” *Econometrica*, 46: 33-50.

Koenker, Roger (2005) *Quantile Regression,* Cambridge University Press, Cambridge.

Komlos, John. “The Height and Weight of West Point Cadets: Dietary Change in Antebellum America.” *Journal of Economic History* 47, no. 4 (December 1987):

897-927.

Komlos, John. “Toward an Anthropometric History of African-Americans: The Case of the Free Blacks in Antebellum Maryland.” in *Strategic Factors in Nineteenth Century American Economic History: A Volume to Honor Robert W. Fogel,* edited by Claudia Goldin and Hugh Rockoff. Chicago: University of Chicago Press. 1992, 297-329.

Komlos, John and Peter Coclanis. “On the Puzzling Cycle in the Biological Standard of Living: The Case of Antebellum Georgia.” *Explorations in Economic History.* 34, no. 4 (October, 1997): 433-59.

Komlos, John and Jörg Baten (2004) “Anthropometric Research and the Development of Social Science History. Social Science History. 28: 191-210.

Le Roy Ladurie, E., 1979, The Conscripts of 1968: A Study of the Correlation between Geographical Mobility, Delinquency and Physical Stature and Other Aspects of the Situation of the Young Frenchman Called to Do Military Service that Year. In: Reynolds B, Reynolds S, editors. *The Territory of the Historian*, (Chicago: University of Chicago Press). 33-60.

Loomis, W. Farnsworth, 1967, “Skin-Pigment Regulation of Vitamin-D Biosynthesis in Man: Variation in Solar Ultraviolet at Different Latitudes may have Caused Racial Differentiation in May,” *Science*, pp. 501-506.

Margo, Robert and Richard Steckel. “Heights of American Slaves: New Evidence on Nutrition and Health.” *Social Science History* 6, no. 4 (Fall, 1982): 516-538.

Margo, Robert and Richard Steckel. 1992, “The Nutrition and Health of Slaves and antebellum Southern whites.” in *Without Consent or Contract: Conditions of*

Slave Life and the Transition to Freedom, edited by R. W. Fogel and S. L. Engerman, New York: Norton, 508-521.

Metzer, Jacob. M. "Rational Management, Modern Business Practices and Economies of Scale in Antebellum Southern Plantations." *Explorations in Economic History* 12, n. 2 (April, 1975): 123-150.

Nesby-O'Dell, Shanna, Kelley Scanlon, Mary Cogswell, Cathleen Gillesie, Bruce Hollis Anne Looker, Chris Allen, Cindy Doughertly, Elaine Gunter, and Barbara Bowman. "Hypovitaminosis D Prevalence and Determinants among African-American and White Woman of Reproductive Age: Third National Health and Nutrition Examination Survey, 1988-1994." *American Journal Clinical Nutrition 76*. 2002. pp. 187-192.

Nicholas, Stephen and Richard Steckel, "Heights and Living Standards of English Workers During the Early Years of Industrialization." *Journal of Economic History*. 51(4), 1991, pp. 937-957.

Norman, Anthony, "Sunlight, Season, Skin Pigmentation, Vitamin D and 25-hydroxyvatamin D: Integral Components of the Vitamin D Endocrine System," American Journal of Clinical Nutrition, 67. 1998, pp. 1108-1110.

Nyström-Peck, Maria and Olle Lundberg, 1995, "Short Stature as an Effect and Social Conditions in Childhood," *Social Science Medicine 41(5),* pp. 733-738.

Sokoloff, K. & Villaflor, G. (1982) "Early Achievement of Modern Stature in America," *Social Science History* 6, 453-481.

Steckel, Richard, 1979, "Slave Height Profiles from Coastwise Manifests," *Explorations in Economic History 16*, pp. 363-380.

Sunder, Marco (2004) “The Height of Tennessee Convicts: Another Pieces of the “Antebellum Puzzle”. *Economics and Human Biology*. pp. 75-86.

Tangpricha, Vin, Elizabeth Pearce, Tai Chen, and Michael Holick, 2002, “Vitamin D Insufficiency among Free-Living Health Young Adults,” *The American Journal of Medicine v. 112,* pp. 659-662.

Tanner, James M, 1977, “Human Growth and Constitution,” in Harrison, GA, Weiner, JS, Tanner, JM, and Barnicot, NA (eds) *Human Biology: an Introduction to Human Evolution, Variation, Growth and Ecology.* pp. 301-384.

Tortolani, Justin, Edward McCarthy, Paul Sponseller, 2002, “Bone Mineral Density Deficiency in Children,” *Journal of the American Academy of Orthopedic Surgeons,* 10(1) pp. 57-66.

Utterlinden, André, Yue Fang, Joyce B.J. van Meurs, Huibert A. P. Pols, Johannes P.T.M van Leeuwen, “Genetic and Biology of Vitamin D Receptor Polymorphisms,” *Gene,* 338, 2004, pp. 143-156.

Wannamethee, S. Goya, Peter Whincup, Gerald Shaper and Mary Walker, “Influence of Father’s Social Class on Cardiovascular Disease in Middle-Aged Men,” *The Lancet*, 348:9, 1996, pp.1259-63.

Wardlaw, G.M., J.S. Hampl, and R.A. Disilestro, 2004, *Perspectives in Nutrition, 6th ed.*, New York: McGraw-Hill, pp. 394-397.

Xiong, E-H, F-H Xu, P-Y Liu, H Shen, J-R Long, L Elze, R R Recker and H-W Deng, “Vitamin D Receptor Gene Polymorphisms are Linked to and Associated with Adult Height,” *Journal of Medical Genetics,* 42, 2004, pp. 228-234.

Y-Z Liu, F-H Shen, H Deng, Y-J Liu, L-J Zhao, V Dvornyk, T Conway, J-L Li, Q-Y Huang, K M Davies, R R Recker, and H-W Deng, "Confirmation Linkage Study in Support of the X Chromosome Harbouring a ATL Underlying Human Height Variation," *Journal of Medical Genetics,* 40, pp. 825-831.

CESifo Working Paper Series

for full list see www.cesifo-group.org/wp
(address: Poschingerstr. 5, 81679 Munich, Germany, office@cesifo.de)

2501 Andrew Clark, Andreas Knabe and Steffen Rätzel, Boon or Bane? Others' Unemployment, Well-being and Job Insecurity, December 2008

2502 Lukas Menkhoff, Rafael R. Rebitzky and Michael Schröder, Heterogeneity in Exchange Rate Expectations: Evidence on the Chartist-Fundamentalist Approach, December 2008

2503 Salvador Barrios, Harry Huizinga, Luc Laeven and Gaëtan Nicodème, International Taxation and Multinational Firm Location Decisions, December 2008

2504 Andreas Irmen, Cross-Country Income Differences and Technology Diffusion in a Competitive World, December 2008

2505 Wenan Fei, Claude Fluet and Harris Schlesinger, Uncertain Bequest Needs and Long-Term Insurance Contracts, December 2008

2506 Wido Geis, Silke Uebelmesser and Martin Werding, How do Migrants Choose their Destination Country? An Analysis of Institutional Determinants, December 2008

2507 Hiroyuki Kasahara and Katsumi Shimotsu, Sequential Estimation of Structural Models with a Fixed Point Constraint, December 2008

2508 Barbara Hofmann, Work Incentives? Ex Post Effects of Unemployment Insurance Sanctions – Evidence from West Germany, December 2008

2509 Louis Hotte and Stanley L. Winer, The Demands for Environmental Regulation and for Trade in the Presence of Private Mitigation, December 2008

2510 Konstantinos Angelopoulos, Jim Malley and Apostolis Philippopoulos, Welfare Implications of Public Education Spending Rules, December 2008

2511 Robert Orlowski and Regina T. Riphahn, The East German Wage Structure after Transition, December 2008

2512 Michel Beine, Frédéric Docquier and Maurice Schiff, International Migration, Transfers of Norms and Home Country Fertility, December 2008

2513 Dirk Schindler and Benjamin Weigert, Educational and Wage Risk: Social Insurance vs. Quality of Education, December 2008

2514 Bernd Hayo and Stefan Voigt, The Relevance of Judicial Procedure for Economic Growth, December 2008

2515 Bruno S. Frey and Susanne Neckermann, Awards in Economics – Towards a New Field of Inquiry, January 2009

2516 Gregory Gilpin and Michael Kaganovich, The Quantity and Quality of Teachers: A Dynamic Trade-off, January 2009

2517 Sascha O. Becker, Peter H. Egger and Valeria Merlo, How Low Business Tax Rates Attract Multinational Headquarters: Municipality-Level Evidence from Germany, January 2009

2518 Geir H. Bjønnes, Steinar Holden, Dagfinn Rime and Haakon O.Aa. Solheim, ‚Large' vs. ‚Small' Players: A Closer Look at the Dynamics of Speculative Attacks, January 2009

2519 Jesus Crespo Cuaresma, Gernot Doppelhofer and Martin Feldkircher, The Determinants of Economic Growth in European Regions, January 2009

2520 Salvador Valdés-Prieto, The 2008 Chilean Reform to First-Pillar Pensions, January 2009

2521 Geir B. Asheim and Tapan Mitra, Sustainability and Discounted Utilitarianism in Models of Economic Growth, January 2009

2522 Etienne Farvaque and Gaël Lagadec, Electoral Control when Policies are for Sale, January 2009

2523 Nicholas Barr and Peter Diamond, Reforming Pensions, January 2009

2524 Eric A. Hanushek and Ludger Woessmann, Do Better Schools Lead to More Growth? Cognitive Skills, Economic Outcomes, and Causation, January 2009

2525 Richard Arnott and Eren Inci, The Stability of Downtown Parking and Traffic Congestion, January 2009

2526 John Whalley, Jun Yu and Shunming Zhang, Trade Retaliation in a Monetary-Trade Model, January 2009

2527 Mathias Hoffmann and Thomas Nitschka, Securitization of Mortgage Debt, Asset Prices and International Risk Sharing, January 2009

2528 Steven Brakman and Harry Garretsen, Trade and Geography: Paul Krugman and the 2008 Nobel Prize in Economics, January 2009

2529 Bas Jacobs, Dirk Schindler and Hongyan Yang, Optimal Taxation of Risky Human Capital, January 2009

2530 Annette Alstadsæter and Erik Fjærli, Neutral Taxation of Shareholder Income? Corporate Responses to an Announced Dividend Tax, January 2009

2531 Bruno S. Frey and Susanne Neckermann, Academics Appreciate Awards – A New Aspect of Incentives in Research, January 2009

2532 Nannette Lindenberg and Frank Westermann, Common Trends and Common Cycles among Interest Rates of the G7-Countries, January 2009

2533 Erkki Koskela and Jan König, The Role of Profit Sharing in a Dual Labour Market with Flexible Outsourcing, January 2009

2534 Tomasz Michalak, Jacob Engwerda and Joseph Plasmans, Strategic Interactions between Fiscal and Monetary Authorities in a Multi-Country New-Keynesian Model of a Monetary Union, January 2009

2535 Michael Overesch and Johannes Rincke, What Drives Corporate Tax Rates Down? A Reassessment of Globalization, Tax Competition, and Dynamic Adjustment to Shocks, February 2009

2536 Xenia Matschke and Anja Schöttner, Antidumping as Strategic Trade Policy Under Asymmetric Information, February 2009

2537 John Whalley, Weimin Zhou and Xiaopeng An, Chinese Experience with Global 3G Standard-Setting, February 2009

2538 Claus Thustrup Kreiner and Nicolaj Verdelin, Optimal Provision of Public Goods: A Synthesis, February 2009

2539 Jerome L. Stein, Application of Stochastic Optimal Control to Financial Market Debt Crises, February 2009

2540 Lars P. Feld and Jost H. Heckemeyer, FDI and Taxation: A Meta-Study, February 2009

2541 Philipp C. Bauer and Regina T. Riphahn, Age at School Entry and Intergenerational Educational Mobility, February 2009

2542 Thomas Eichner and Rüdiger Pethig, Carbon Leakage, the Green Paradox and Perfect Future Markets, February 2009

2543 M. Hashem Pesaran, Andreas Pick and Allan Timmermann, Variable Selection and Inference for Multi-period Forecasting Problems, February 2009

2544 Mathias Hoffmann and Iryna Shcherbakova, Consumption Risk Sharing over the Business Cycle: the Role of Small Firms' Access to Credit Markets, February 2009

2545 John Beirne, Guglielmo Maria Caporale, Marianne Schulze-Ghattas and Nicola Spagnolo, Volatility Spillovers and Contagion from Mature to Emerging Stock Markets, February 2009

2546 Ali Bayar and Bram Smeets, Economic and Political Determinants of Budget Deficits in the European Union: A Dynamic Random Coefficient Approach, February 2009

2547 Jan K. Brueckner and Anming Zhang, Airline Emission Charges: Effects on Airfares, Service Quality, and Aircraft Design, February 2009

2548 Dolores Messer and Stefan C. Wolter, Money Matters – Evidence from a Large-Scale Randomized Field Experiment with Vouchers for Adult Training, February 2009

2549 Johannes Rincke and Christian Traxler, Deterrence through Word of Mouth, February 2009

2550 Gabriella Legrenzi, Asymmetric and Non-Linear Adjustments in Local Fiscal Policy, February 2009

2551 Bruno S. Frey, David A. Savage and Benno Torgler, Surviving the Titanic Disaster: Economic, Natural and Social Determinants, February 2009

2552 Per Engström, Patrik Hesselius and Bertil Holmlund, Vacancy Referrals, Job Search, and the Duration of Unemployment: A Randomized Experiment, February 2009

2553 Giorgio Bellettini, Carlotta Berti Ceroni and Giovanni Prarolo, Political Persistence, Connections and Economic Growth, February 2009

2554 Steinar Holden and Fredrik Wulfsberg, Wage Rigidity, Institutions, and Inflation, February 2009

2555 Alexander Haupt and Tim Krieger, The Role of Mobility in Tax and Subsidy Competition, February 2009

2556 Harald Badinger and Peter Egger, Estimation of Higher-Order Spatial Autoregressive Panel Data Error Component Models, February 2009

2557 Christian Keuschnigg, Corporate Taxation and the Welfare State, February 2009

2558 Marcel Gérard, Hubert Jayet and Sonia Paty, Tax Interactions among Belgian Municipalities: Does Language Matter?, February 2009

2559 António Afonso and Christophe Rault, Budgetary and External Imbalances Relationship: A Panel Data Diagnostic, February 2009

2560 Stefan Krasa and Mattias Polborn, Political Competition between Differentiated Candidates, February 2009

2561 Carsten Hefeker, Taxation, Corruption and the Exchange Rate Regime, February 2009

2562 Jiahua Che and Gerald Willmann, The Economics of a Multilateral Investment Agreement, February 2009

2563 Scott Alan Carson, Demographic, Residential, and Socioeconomic Effects on the Distribution of 19th Century US White Statures, February 2009