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In the shadow of coal: How large-scale industries contributed to present-day regional differences in personality and well-being

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Abstract

Recent research has identified regional variation of personality traits within countries but we know little about the underlying drivers of this variation. We propose that the Industrial Revolution, as a key era in the history of industrialized nations, has led to a persistent clustering of well-being outcomes and personality traits associated with psychological adversity via processes of selective migration and socialization. Analyzing data from England and Wales, we examine relationships between the historical employment share in large-scale coal-based industries (coal mining and steam-powered manufacturing industries that used this coal as fuel for their steam engines) and today's regional variation in personality and well-being. Even after controlling for possible historical confounds (historical energy supply, education, wealth, geology, climate, population density), we find that the historical local dominance of large-scale coal-based industries predicts today's markers of psychological adversity (lower Conscientiousness [and order facet scores], higher Neuroticism [and anxiety and depression facet scores], lower activity [an Extraversion facet], and lower life satisfaction and life expectancy). An instrumental variable analysis, using the historical location of coalfields, supports the causal assumption behind these effects (with the exception of life satisfaction). Further analyses focusing on mechanisms hint at the roles of selective migration and persisting economic hardship. Finally, a robustness check in the U.S. replicates the effect of the historical concentration of large-scale industries on today's levels of psychological adversity. Taken together, the results show how today's regional patterns of personality and well-being may have their roots in major societal changes underway decades or centuries earlier.

Key Words: Industrial Revolution, regional well-being, adversity, Big Five personality traits, historical factors

In the shadow of coal: How large-scale industries contributed to regional personality and well-being differences

"And was Jerusalem builded here,
Among these dark Satanic Mills?"
- From the unofficial national anthem of England "Jerusalem" -
(Lyrics: "And did those feet in ancient times" by William Blake)

On December 18th, 2015, the miners of Kellingley Colliery in North Yorkshire, U.K., completed their shifts for the last time, finally bringing an end to production at the facility (BBC, 2016). As the last operating deep coal mine in the U.K., the pit's closure marked an endpoint in the long history of coal-based industrialization that helped to create the foundations of modern society. With the end of coal-based industrialization, we are left only with relics of that bygone era, housed in museums such as the UNESCO World Heritages "Völklingen Ironworks" in the Saarland coal region of Germany and the "Blaenavon Industrial Landscape" in the old coal region of Wales, where visitors can learn about what life was like in the once thriving centers of the Industrial Revolution. For the people who still live in these old industrial regions there is no need to visit a museum to learn about the impact of coal. Every day, they experience the persistent economic and social legacy of the rise and fall of the large-scale coal-based industries. Here, we look at the evidence for another more "hidden" legacy of coal: Sustained psychological consequences, affecting the well-being of the populations now living in the old coal regions. A great proportion of the population of old industrial nations still live in old industrial regions today (e.g., in the U.K. around 45% of the national population; Office for National Statistics of the U.K.), so the issue is far from trivial.

There are compelling theoretical and empirical reasons for supposing that the massive concentration of large-scale coal-based industries (e.g., coal mining and steam-powered manufacturing industries that used this coal as fuel for their steam engines) could have left a lasting psychological imprint in the local cultures of the old industrial regions. The Industrial

Revolution is widely associated with the staggering increases in manufacturing that were facilitated by the technical improvements of the stationary steam engine as power source. These changes had tremendous economic and social effects throughout much of the Western World, but their impact was felt perhaps most strongly in old industrial regions; these regions attracted the physical labor to staff the factories that were powered by the coal from the nearby coalfields. Then, over a century later, as technologies advanced and coal reserves were diminished, old industrial regions no longer had a place in the shifting economic structure and entire populations were left without work. Consequently, these regions are now some of the most economically deprived areas in highly industrial nations (Müller, Finka, & Lintz, 2006). It is well documented that living in deprived areas can be harmful to one's well-being and health. Scores of studies converge to suggest that high unemployment and crime, and low levels of education are related to depression and poor physical health, over and above the effects of low family income (Cutrona, Wallace, & Wesner, 2006; Evans, Wells, Chan, & Saltzman, 2000). Furthermore, people who live in economically deprived areas are at greater risk for health problems, drug abuse, and obesity, which perpetuates poor health and inequality (Banks, Marmot, Oldfield, & Smith, 2006; Glymour, Avendaño, & Berkman, 2007; Jokela, 2015; Marmot &Wilkinson, 2005; Nettle, 2010).

The present research seeks to cast light on the hidden legacy of historical massive industrialization and the subsequent age of steam on the people who live there. Specifically, we study the potential adverse effects on the psychology of the people living in these old industrial regions. We argue that psychological adversity "runs deep" in these regions, expressed not only in the actual well-being of these people but also in their personality traits that are linked to well-being. We therefore first examine psychological adversity as it is conventionally studied, in terms of diminished well-being (measured via life satisfaction and life expectancy in our study). We also examine psychological adversity from a new angle, focusing on some potentially more enduring adverse effects, in terms of changes to the

personality traits found in the old industrial regions: this second facet of psychological adversity ties in with recent work that has established regional differences in personality traits but has yet to identify the potential causal mechanisms driving the uneven distribution of personality across regions (Rentfrow, 2014).

The Age of Steam: The Central Role of Coal and Steam in the Industrial Revolution

The Industrial Revolution, which began in Great Britain before it spread to other parts of Western Europe and Northern America, marked a major turning point in the cultural, social, and technological history of humankind (McCloskey, 2004). The revolutionary historical changes ushered in during the Industrial Revolution and their imprint on today's economies and social infrastructures are well documented; however, the historical changes' imprint on the more latent, psychological factors influencing a wide range of socio-economic outcomes in the local population and the region as a whole are less understood.

The invention and spread of the stationary steam engine was a particularly important driver of the Industrial Revolution, which is thus often regarded as the "age of steam". Wind, water, horse, and human-power remained major energy sources for driving small machines, but steam power delivered the energy necessary for establishing and running large-scale industries and factories, which provided new jobs for hundreds of thousands of workers. With this rise of large-scale industries and factories, and thus early massive industrialization, steam power quickly became the dominant power source in industrialized nations. Today, steam-related industries have lost their dominance in local economies. As an illustration, note the change in prevalence of chimneys in the inset pictures shown in Figure 1, between Manchester during the Industrial Revolution (also known as "Cottonopolis" due to its massive steam-powered textile industry) and current-day Manchester, where steam-powered industries no longer dominate.

These steam-powered regions were relatively independent of geographical proximity to wind and water supply but they were, naturally, strongly dependent on the fuel of the

"steam age" – coal. Hence, these industrialized centers usually emerged in regions with geographical proximity to coalfields because coal was a bulky commodity with high transportation costs (Crafts & Mulatu, 2005; Crafts & Wolf, 2013). Examples of such coal-based, large-scale industries include steam-intensive industries such as textile production, metal manufacturing, bricks and pottery, and, of course, coal mining itself (see Table S1 for an overview of these industries). The availability of cheap coal and the adoption of the steam engine as a power source resulted in an unprecedented growth in factory size and a high division of labor.

Potential Mechanisms linking the Industrial Revolution to Regional Variation in Psychological Characteristics

Prior research has established substantial regional variation in psychological characteristics, such as personality traits and well-being (Diener, Oishi, & Lucas, 2003: Frey & Stutzer, 2000; OECD, 2011; Rentfrow, 2014; Rentfrow, Gosling, & Potter, 2008; Rentfrow, Jokela, & Lamb, 2015; The Gallup Organization, 2007). In our analysis, we focus on the historical concentration of large-scale coal-based industries as a potential driver of such regional differences. There are multiple ways through which an historical event, like the Industrial Revolution, could affect present-day psychological traits.

One way is through a *Change-that-Persists*, that is, when the original event precipitated enduring changes that were sustained across time, can still be felt today. An example of this process would be if the Industrial Revolution caused people with certain personalities to move into certain areas and those "founder effects" have endured (e.g., through socialization or genetic effects across generations living there) until today. Another way is through a *Chain-of-Events*, that is, when the original event set in motion a sequence of events, with one of these more recent events causing present-day change. An example of this would be if the Industrial Revolution created local economies that were overly reliant on a

single form of industrial production such that when that form of production became obsolete, the local economy collapsed and it was the economic collapse and all its implications that affected local residents.

Of course, these two sets of causal changes are gross simplifications because it is likely that there are multiple processes underway, quite possibly interacting with one another in complex ways. Nonetheless, it is possible to make conceptual distinctions between the *Change-that-Persists* and *Chain-of-Events* processes and these distinctions can guide the questions that are asked and the analyses that are undertaken. One key step in delineating such processes is dividing the sequence of events into distinct time periods. Here we divide the timeline into three broad categories: Pre-event period, Event period, and Post-event period. In the present case, the event is the age of steam that was precipitated by the Industrial Revolution. The *Pre-Steam period* would last until sometime around the 1780s, the *Steam-Age period* would run from the 1780s until the First World War (1914), and the *Post-Steam period* would start around 1914. Obviously, events do not start and stop in a vacuum; a sequence of events led up to the Industrial Revolution and another sequence of events preceded those, and so on and so on. Nonetheless, for any given analysis, as we shall see below, such a division of time periods can be helpful.

Regardless of whether the causal process consists of a *Change-that-Persists* or a *Chain-of-Events*, what are the mechanisms by which historical events, such as the age of steam, could leave an imprint on the psychological adversity experienced in different geographic regions? In their theory on the emergence and persistence of regional psychological difference, Rentfrow et al., (2008) posit selective migration and socialization as two key mechanisms for shaping the psychological traits of regions. Below we describe each of these mechanisms, showing how each has the potential to drive the emergence and persistence of unique patterns of psychological adversity in the old industrial regions.

Selective Migration Patterns

We argue here that there are two broad ways selective migration could have resulted in the uneven distribution of psychological adversity. First, people from areas experiencing high levels of hardship could be particularly likely to migrate, driven to move (to more promising regions) by their desperately impoverished living conditions. Second, even within these impoverished conditions, some people may have been more likely to migrate than others. In the following, we describe such patterns of systematic migration for the *Steam-Age* and *Post-Steam periods*.

The advent of the Industrial Revolution precipitated a massive influx of workers to regions that became centers of the age of steam. Most of the coalfields already attracted industry and higher population densities long before the Industrial Revolution because coal provided a cheap energy source for industries needing heat in the production process, such as smithing, ironworking, lime-burning, salt, and textiles (Hatcher, 1993). However, the concentration of industry and people was accelerated massively during the Industrial Revolution (Landes, 1969). This concentration changed the social and cultural landscape within the early industrialized nations in an enduring way. The urban agglomerations around the steam-powered industries and factories grew rapidly, with whole communities forming cultural identities and class structures (e.g., the working class; Thompson 1966).

In Britain, major waves of labor migration during the Industrial Revolution comprised both short-distance migration, with a population influx to the industrial centers from the surrounding rural areas, and long-distance migration, mostly from Ireland and Scotland (Redford & Chaloner, 1976). In terms of the migrants' occupational backgrounds, "workers coming from agriculture by far outnumbered the rest" (p. 67). One major driver of the labor migration from the rural areas and from Ireland and Scotland was poverty and distress in the migrants' home living conditions. For example, the acute agricultural depression in the rural areas of Britain after the Napoleonic Wars and the desire to escape poor living conditions drove much of the migration. Hence, it is likely that the migration patterns associated with the

Steam-Age period were selective, with workers and their families migrating to industrial centers out of necessity, with hopes of better lives.

In the *Post-Steam period*, the major decline of the former industrial regions has led to negative net migration of the working populations in these regions, with more people leaving than entering (Beatty, Fothergill, & Powell, 2007; Heim, 1997). Again, there is evidence to think that this wave of out-migration would also be selective. In this case, research suggests it would be the optimistic individuals, least susceptible to major hardship, who would have the positive and agentic mindset needed to undertake such migration and to seek new environments that offer new economic opportunities (Jokela, 2015; Jokela, Bleidorn, Lamb, Gosling, & Rentfrow, 2015; Jokela, Elovainio, Kivimäki, & Keltikangas-Järvinen, 2008; Kitayama, Ishii, Imada, Takemura, & Ramaswamy, 2006). If this is true, it would further amplify the clustering of high levels of psychological adversity in the old industrial regions.

To sum up the selective migration effects, historical analyses suggest that desperation drove individuals from impoverished rural regions to disproportionately populate the old industrial regions during the *Steam-Age period*. While these impoverished rural regions might have been characterized by a generally high level of psychological adversity, which was imprinted in the general personality structure of this rural population due to socialization effects, we can speculate that within these impoverished rural regions people still differed in their levels of psychological adversity. Therefore, some people may have been more likely to migrate to the industrial centers than others from the same regions. It is possible that it was particularly those with the *lowest* psychological adversity within these impoverished regions who moved to the industrial centers because this group could rely on better psychological resources than others in these rural regions. Such resources might be necessary for such major migration efforts that were not only motivated by the desire to leave major hardship, but also by the specific promises and opportunities associated with the thriving industrial centers (it might require at least some degree of optimism and resilience to actively embrace those

opportunities). This group migrating to the industrial centers should, on average, still be higher in psychological adversity compared to the initial levels of psychological adversity in the emerging industrial centers in the *Pre-Steam period* (because these thriving industrial regions were not so extremely impoverished as the rural regions), so this selective influx would serve to *increase* the general psychological adversity level in the industrial centers during the *Steam-Age period*. In the *Post-Steam period*, research suggests it may be (again) those individuals lowest on psychological adversity within the old industrial regions who left these depressed old industrial areas in search of better opportunities. These two effects (selective influx during the *Steam-Age period* and selective outflow during the *Post-Steam period*) could combine to yield a regional association between a concentration of large-scale coal-based industries during the Industrial Revolution and today's psychological adversity.

Socialization Effects

In addition to selective migration, socialization effects are also likely to play a key role. Again, we can differentiate between the historical depletion processes in the *Steam-Age period* and more recent processes in the *Post-Steam period* that maintain, or even amplify, the initial clustering of high psychological adversity in the old industrial regions. During the *Steam-Age period*, the massive concentration of large-scale coal-based industries, and thus the rapid urbanization in these early-industrialized centers, often led to harsh conditions for living (air and water pollution, poor sanitation, over-crowding) and working (child labor, long working hours, dangerous conditions: Thompson, 1966). For example, coal-mining operations generate particulate matter and gases, such as methane, sulfur dioxide, and carbon monoxide, which are major air pollutants. Such air pollutants have been shown to impair cognitive functions and elicit depressive-like behaviors (Fonken et al., 2011) and to affect individuals via epigenetic mechanisms (e.g., regarding processes of DNA methylation and gene expression: Bind et al., 2014; Heijmans et al., 2008), which can be transmitted to successive

generations (Dias & Ressler, 2014). Thus, life for people in these industrial centers was directly affected by coal-based industrialization, regardless of whether they worked in mining or manufacturing.

Scholars from sociology, economics, and psychology, have long acknowledged the socialization effects of everyday working conditions and experiences. Famous historical examples are Karl Marx's (1859) "being determines consciousness" principle (i.e., the notion that work conditions and experiences shape the thinking and identity of the workers) and Adam Smith's (1776) assertion that the division of labor (and thus highly specialized and repetitive work tasks) comes with detrimental psychosocial effects for the workers, such as ignorance, inability in judging, and "the expense of […] intellectual, social, and martial virtues" (p. 850). Such a division of labor was a key feature in these industrial centers. The working conditions in these industrial centers were highly repetitive, and also dangerous and physically taxing. Research suggests that monotonous work, with low personal control and job autonomy, leads to reduced subjective well-being (e.g., low job satisfaction) and elevated psychobiological stress levels (Humphrey, Nahrgang, & Morgeson, 2007; Lundberg, Granqvist, Hansson, Magnusson, & Wallin, 1989). In sociological research, socialization through work conditions and experiences, such as job-related autonomy and task variety, is an empirically validated explanatory model for the persisting societal stratification in society (Kohn & Schooler, 1983). Many studies have illustrated a "long-arm of the job", which refers to the shaping of personality factors through work conditions and experiences (Frese, Garst, & Fay, 2007; Kohn & Schooler, 1982; Roberts, Caspi, & Moffitt, 2003). This process also can apply to the influence of parents' working conditions and experiences in how they raise their offspring (Crouter, Bumpus, Maguire, & McHale, 1999) by, for example, transmitting values to their children that were socialized through their work experiences (Luster, Rhoades, & Haas, 1989).

In the context of historical economic institutions in China, a recent study found that rice cultivation led to a higher prevalence of holistic and interdependent thinking among residents of rice-culture regions (Talhelm et al., 2014). The authors explain their findings in terms of a cultural imprint of these economic institutions on the local population via, for example, work conditions and experiences associated with rice cultivation (e.g., work that requires collectivistic and conflict avoiding behavior), and related local formal and informal institutions through which local populations are influenced and shaped. Hence, there is already evidence showing that economic institutions dominating local economies over long periods can have a lasting imprint on the psychological make-up of a region via work demands and conditions. However, one could question whether this Chinese case is really comparable to the present study because the regional differences in agriculture still exist today in China, whereas the large-scale, coal-based industries have long since lost their regional dominance. Nevertheless, we should keep in mind that large-scale coal-based industries dominated the social, economic, and cultural life for more than 150 years in the old industrial regions. After dominating a region for so long, the cultural imprint of these industries may indeed remain, even after their dominance has subsided. Indeed, research has demonstrated the enduring cultural effects of such economic institutions, even after the institutions themselves have long since receded (e.g., Falck, Fritsch, & Heblich, 2011; Guiso, Sapienza, & Zingales, 2008).

With respect to more recent socialization processes during the *Post-Steam period*, economists stress that the historical concentration of large-scale coal-based industries in a region has produced lasting economic problems, which, in turn, have shaped the region's cultural life and the economic situation of its population (Beatty & Fothergill, 1996). The former industrial coal-based centers, such as in the Ruhr region in Germany, the Rust Belt in the U.S., or in the coal regions of Great Britain are all associated with unhealthy present-day economies (Beatty & Fothergill, 1996; Gardiner, Martin, Sunley, & Tyler, 2013; Gresser,

2001; Teaford, 1993). The long dominance of large-scale industries impaired structural change towards services and knowledge-based industries in these regions. As generations of employees worked in a few large local firms, the population in these regions also lacked an "entrepreneurial spirit" to act on opportunities, which resulted in substantially lower entrepreneurship rates and low economic growth (Glaeser, Kerr, & Kerr, 2015; Stuetzer et. al. 2016). Consequently, when these dominant industries went into decline, there were few alternative employment opportunities, which led to high unemployment rates and out-migration from these regions (Beatty & Fothergill, 1996; Champion, 2005). Economic changes of various kinds have meant that almost all the old industrial regions have been depressed since the 1970s and continue to have high levels of unemployment. Furthermore, modern electricity freed the manufacturing industry's dependence on proximity to a source of coal, thereby allowing it to relocate to where labor was cheaper and where trade unions had less influence.

Such persistent economic hardship is likely to increase psychological adversity. For example, Gallo and Matthews (2003) and Matthews and Gallo (2011) propose that the stress associated with chronically low socioeconomic status diminishes the reserve capacity of an individual to cope with limited access to resources, lower social status, and reduced health status. A variety of research found that particularly chronic, or cumulative, economic hardship often leaves a negative imprint on physical, cognitive, psychological, and social functioning that maintains well-being and health (Lynch, Kaplan, & Shema, 1997). The effects of economic hardship extend into the communities well beyond the specific individuals who are experiencing it directly; for example, job losses inflict anxiety and frustration in communities, worsening adolescent mental health and lowering academic performance even in families that did not experience job loss (Ananat, Gassman-Pines, Francis, & Gibson-Davis, 2017).

Taken together, we expect a complex system of selective migration and socialization processes to produce a distinct psychological pattern in old industrial regions. Figure 1

presents a summary of these potential mechanisms, distinguishing between more *historical* mechanisms during the *Pre-Steam* and *Steam-Age periods*, and more *recent* mechanisms exerting their influence during the *Post-Steam period*.

The "Psychological Adversity" Hypothesis

Our historical analysis above suggests that the social and economic conditions of the past could have shaped the psychological make-up of regions (via selective migration and socialization effects). As we outline below, we expect to find a distinct regional personality pattern such that local populations from regions with an industrial heritage are associated with higher levels of psychological adversity, measured both in conventional patterns of lower well-being (as measured by regional differences in life satisfaction and life expectancy) and in personality traits associated with adversity (as measured by regional variation in Big Five personality traits and their sub-facets), compared with local populations from other regions.

Personality traits, such as the Big Five, are reliable markers of psychological adversity. Adversity is usually associated with higher scores in Neuroticism, and lower scores in Extraversion, Agreeableness, Openness, and Conscientiousness (Asendorpf, Borkenau, Ostendorf, & Van Aken, 2001; Nakaya, Oshio, & Kaneko, 2006; Robins, John, Caspi, Moffitt, & Stouthamer-Loeber, 1996). With the exception of Openness, such a personality pattern is often also directly associated with lower well-being. A prominent notion in well-being research is that personality differences are a major driver of well-being differences because the latter are "reflections of enduring dispositions" (McCrae & Costa 1991, p. 228). Soto and Luhmann (2013) argue that "people with different personalities chronically experience (a) different balances of positive and negative affect, (b) different balances of positive and negative life events, and (c) different reactions to objectively similar events, all of which predict life satisfaction" (p. 47). Chamorro-Premuzic, Bennett, & Furnham, (2007) stress that, "personality traits are arguably the most robust predictors of happiness, if not the major determinant" (p. 1634). Friedman (2000) emphasizes the link

between personality and health, arguing that, “this is not because there is a disease-prone personality with simple, direct links to ill health, but rather primarily because certain people wind up with unhealthy habits and behaviors, an unbalanced socio-emotional and psychophysiological style, and environments not conducive to good health” (p. 1103).

Meta-analytic results have confirmed that personality traits are important and robust predictors of well-being and happiness. For example, higher life satisfaction is predicted by higher levels of Conscientiousness, Extraversion, and Agreeableness, and lower levels of Neuroticism (Steel, Schmidt, & Schultz, 2008). Furthermore, Conscientiousness is a particularly important predictor of health-related behaviors (Bogg & Roberts, 2004, 2013); for example, life expectancy/longevity shows a substantial positive relationship to Conscientiousness (Bogg & Roberts 2004; Friedman et al., 1993). Overall, there is substantial empirical evidence indicating that low Conscientiousness, Extraversion, and Agreeableness, and high Neuroticism are reliable markers of psychological adversity (Chamorro-Premuzic et al., 2007).

Assuming a lasting “problematic” imprint of the Industrial Revolution and the subsequent age of steam on local personality make-up (via the mechanisms explained above), we expected to find a pattern indicative of high psychological adversity (i.e., lower regional levels in Conscientiousness, Extraversion, Openness, and Agreeableness, and higher regional levels in Neuroticism; lower levels in well-being) to be particularly prevalent today in the old industrial centers, when compared to other regions that were not so heavily exposed to the detrimental psychosocial effects of the Industrial Revolution. Based on this hypothesis, we examined whether regions today systematically differ in their local personality and well-being as a function of their industrial history. We then attempt to examine one of the causes of these effects by employing an instrumental variable analysis that uses the historical distance to the nearest coalfield as an exogenous instrument for the historical industry structure. We also take a closer look at potential mechanisms, focusing on recent migration patterns and the role of

persisting economic hardship in old industrial regions. We note upfront that our study is not able to capture all potential mechanisms and their interplay. Finally, to evaluate the robustness of these effects, we examine whether a systematic link between large-scale industries and regional personality and well-being would also be detectable in another major economy that has been shaped by the Industrial Revolution, the U.S.

Our study makes three key contributions. First, our study sheds light on potential origins of regional personality differences, where little research has been done (e.g., Plaut, Markus, Treadway, & Fu, 2012; Talhelm et al., 2014). Knowing more about the origins of regional personality differences is key to understanding the socio-ecological psychology of places and regions (Oishi, 2014) and thus their cultural, economic, social, and political trajectories (Rentfrow et al., 2013). Second, this study is one of the first to quantify the cultural imprint of the Industrial Revolution, arguably one of the most influential and formative epochs in modern history, on today's psychological make-up of regions. Third, by considering a personality approach, we contribute to research exploring the origins of regional differences in well-being (Diener, 2012; Hacking, Muller, & Buchan, 2011; Oswald & Wu, 2011), and thus to the debate on potential drivers of persistent differences in regional well-being (OECD, 2011; The Gallup Organization, 2007).

Method

Regional Level

In our main study, we focus on Great Britain as the prime example of a country shaped by the Industrial Revolution. To compare regions, we examine the contemporary 111 counties of England and Wales (as defined by the spatial layout of 2012), but exclude the Isles of Scilly because of its very small size. We did not incorporate Scotland in our analyses because we use the earliest available data on industry structure from 1813-1820, which does not cover Scotland.

Personality Data

In our main study, we use personality data taken from the BBC Lab UK project. In the U.S. robustness check, we use data collected online at www.outofservice.com (OOS), an Internet website hosting online studies. These two projects include a broad range of measures and have been used to address a wide array of research questions, ranging from age and gender differences in personality and self-esteem to measurement artifacts in personality measurement and regional differences in personality; a full current list of these articles is provided in the online Supplemental Materials. Virtually all of these articles share no conceptual or empirical overlap with the present work. The one other article showing some conceptual overlap with the present paper (Stuetzer et al., 2016: published in *EER*), also used regional industrial history as a predictor of personality. But in that case, the paper focused squarely on entrepreneurship, and sought evidence for a specific configuration of personality traits that our previous work had shown to be linked entrepreneurial behaviors (Obschonka, Schmitt-Rodermund, Silbereisen, Gosling, & Potter, 2013). In other words, we were essentially using the presence of that specific personality type as one of the several indicators of entrepreneurial activity. The current paper is far broader in terms of scope, attempting to understand the regional industrial factors that might contribute to variation in personality traits and their facets, and also in well-being/health. We do not report any results regarding the single Big Five traits (or their facets) in the *EER* paper because the *EER* paper was concerned with only one specific configuration of traits. In addition, the current paper includes the key outcome variables of psychological well-being and population health, which had no role in the *EER* paper (and would have made no sense in it). In short, what both papers have in common is the use of large-scale coal-based industries as an explanatory variable and the context of the Industrial Revolution. But beyond that overlapping Independent Variable, they differ with respect to the key questions they ask. The *EER* paper asks: What causes regional differences in entrepreneurial culture and behavior (as indexed by a number of things including the entrepreneurial personality profile). The current paper asks: What causes

regional differences in personality traits and their facets, and in well-being/health? So the two papers vary in: 1) the topic (entrepreneurship vs. personality, well-being, and health); 2) the corresponding outcome variables (entrepreneurial markers, one of which was the entrepreneurial personality profile, along with start-up rate, and self-employment rates vs: the Big Five personality traits, their facets, and well-being/health); and 3) geographic scope (Great Britain vs. Great Britain and the U.S.). Moreover, the new paper presents novel in-depth analyses such as migration analyses and mediation analyses with economic hardship as mediator.

Both personality datasets that are used in the present study were approved by the relevant ethics committees. Specifically, for the BBC Lab UK dataset, the Psychology Research Ethics Committee of the University of Cambridge approved the research and procedure for obtaining consent in October 2007. Volunteers were told that the survey was designed to assess personality and that by clicking on the link to proceed to the survey they were giving their consent to participate. Informed consent was not requested from the next of kin, caretakers, or guardians on behalf of minors or children because only individuals 18 and older were eligible to participate. Initiating the survey was used as a record of participant consent. For the OOS dataset, the Institutional Review Board of the University of Texas, Austin deemed this study exempt because no identifying information was collected and there was negligible risk to participants.

In our main analysis, we analyze data collected from $N = 381{,}916$ residents in England and Wales. These data were collected between 2009-2011 with a large Internet-based survey designed and administered in collaboration with the British Broadcasting Corporation (BBC) (for evidence of the representativeness of this dataset see Rentfrow et al., 2015). Respondents provided the postcodes of the places where they currently lived and where they grew up.

Personality traits were assessed at the individual-level by means of the Big Five Inventory (BFI; John and Srivastava 1999), which consists of 44 items (5-point Likert-type

rating scale with endpoints at 1 [Disagree strongly] and 5 [Agree strongly]). Analyses of these BFI scales revealed acceptable levels of internal reliability in this dataset (Rentfrow et al., 2015). In the present analysis, we considered both the broad Big Five traits and, to apply a more fine-grained personality perspective, also the two sub-facets of each of the Big Five traits measured with the BFI (Soto & John, 2009; Soto, John, Gosling, & Potter, 2011). The Big Five traits are *Extraversion* (α =.84), *Agreeableness* (α =.71), *Conscientiousness* (α =.78), *Neuroticism* (α =.78), and *Openness* (α =.73). The 10 sub-facets of these Big Five traits are *assertiveness* (α =.83) and *activity* (α =.67) (sub-facets of Extraversion), *altruism* (α =.60) and *compliance* (α =.55) (sub-facets of Agreeableness), *order* (α =.60) and *self-discipline* (α =.72) (sub-facets of Conscientiousness), *anxiety* (α =.76) and *depression* (α =.54) (sub-facets of Neuroticism), and *aesthetics* (α =.69) and *ideas* (α =.66) (sub-facets of Openness). To aggregate the individual level personality data to the regional level, we used the postcode information regarding the current residence of the respondents. As noted in the introduction, a pattern of personality traits associated with psychological adversity consists of lower levels in Conscientiousness, Extraversion, Openness, and Agreeableness, and higher levels in Neuroticism.

A recent geographical analysis of the Big Five data assessed in the BBC Lab U.K. project found substantial regional variation in the Big Five traits (the facets were not analyzed in that study), with meaningful correlations to current socio-economic regional outcome variables (e.g., economic performance, health, political, and social indicators; Rentfrow et al., 2015). The historical roots of these personality differences were not examined.

Well-Being Data

To quantify regional differences in psychological adversity in conventional terms, we considered psychological well-being and population health. Regional psychological well-being was assessed by means of the *life satisfaction* five-item scale (α = .90) from Diener, Emmons, Larsen and Griffin, (1985), which was included in the BBC Lab U.K. questionnaire

(*N* = 381,916 respondents living in England and Wales). Population health was measured by means of regional differences in life expectancy measured in years at birth for the years 2009-2011 (weighted average of both genders). These data come from the Office of National Statistics (ONS).

Historical Industry Structure during the Industrial Revolution

To assess the regional employment share of workers in different industries during the Industrial Revolution we analyzed employment data from the research project "The Occupational Structure of Britain c.1379-1911" (Kitson et al., 2013). One central part of this project is a data set covering the occupation of male inhabitants in England and Wales in the time period 1813-1820. By law, all churches and chapelries tied to the Church of England had to keep registers of baptisms, which included a record of the occupation of the father at the baptism of his child. Based on this information, the "Cambridge Group for the History of Population and Social Structure" created a so-called "Census of adult male employment" (for details of the procedure, see Kitson et al., 2013). The main advantage of this dataset is that it comprises the earliest comprehensive structure of occupations and industries (comparable census data are available only from 1841 onwards). These data on the number of employees in each occupation were available at the historical parish level and were assigned to contemporary counties using Geographic Information Systems (GIS; see Fritsch & Wyrwich, 2014, for a similar approach).

Using these employment data, we computed the male employment share in three major sectors of the economy for the 1813-1820 period: *Employment share in large-scale coal-based industries*, *Employment share in services*, *Employment share in agriculture*. Coal-based industries consisted of the coal mining industry and the three industries that most heavily used coal for combustion in steam engines – metal manufacturers, textiles, and bricks and pottery (see Table S1 for detailed information on the industry characteristics). From Table S1 it is also evident that these industries were large-scale – textiles ranks 2nd out of 15

industries in average plant size and metal manufacturing ranks 4th. This is no surprise because these industries were among the first to adopt the factory system and the assembly line, leading to large economies of scale (Mokyr, 2001). We also expect coal mining to be large-scale (Glaeser et al., 2015) although exact data on historic plant sizes are not available. The cumulated employment share in these industries in the 1813-1820 period was, on average, 8.7% in English and Welsh regions, but with drastic regional differences (min = 0% in Slough and max = 65.7% in Blackburn with Darwen).

Coalfields as an Instrumental Variable

To establish the direction of the effects, it is important to tackle potential endogeneity regarding the relationship between large-scale coal-based industries and regional psychological variables; to do so, we employed the instrumental variable (IV) technique (Angrist, Imbens, & Rubin, 1996), an approach typically employed in economics (e.g., Nunn & Wantchekon, 2011) and also increasingly in psychology (Auger, Farkas, Burchinal, Duncan, & Vandell, 2014; Talhelm et al., 2014). The rationale behind the IV technique is to check for the directionality of hypothesized effects. For example, a variable X is hypothesized to affect variable Y, in other words, variation in X shall explain variation in Y. Unfortunately, one often cannot rule out a reverse effect from Y to X. In that case, variable X is endogenous. In a standard OLS regression setting, the econometric consequence of this endogenous relationship between X and Y is that the variable X is correlated with the error term and thus a standard OLS regression cannot consistently measure the effect of X on Y. In our case, X is the employment share in large-scale coal-based industries and Y are the regional personality traits as well as regional well-being. We expect that industrial structure affects the clustering of regional personality traits and regional well-being. However, one could also ask whether a reverse effect of regional personality and well-being on industry structure could also explain such a relationship. For example, certain industries might have sought out certain regions where a local labor force was characterized by a certain psychological profile. Hence, there

might be a statistical endogeneity problem with respect to the direction of effects in the link between industry structure and regional personality and well-being.

One possible solution for the endogeneity problem is an IV approach. Sometimes, there exists a variable Z that directly affects X, but not directly the dependent variable Y. In that sense Z is an exogenous variable (also often called an exogenous instrument). In our case we use the minimum distance to the nearest coalfields as an exogenous instrument. In the context of industrializing Great Britain in the 18th and 19th centuries, the availability of cheap coal was the driving force for the location of large-scale industries such as textiles and metal manufacturing, which relied heavily on coal for combustion (Crafts & Mulatu, 2005; Crafts & Wolf, 2013; Stuetzer et al., 2016). Figure S1 A-D illustrates the similar geographical distributions of coalfields, low coal prices, and the high employment share in large-scale coal-based industries in industrializing England and Wales. The shorter the distance of a region to a coalfield (Z), the lower the coal prices and, therefore, the higher the employment share in large-scale coal-based industries (X). To localize coalfields we digitized an historic map of coalfields from Hatcher (1993, p. 64). The minimum distance of a county to a coalfield was computed by GIS and refers to the distance between the borders of the nearest coalfield to the borders of the counties.

We can rule out any direct effect of the distance to a coalfield (Z) to the regional personality traits and well-being (Y), which now allows for the IV analysis. In a first step, one uses variation in Z to explain variation in X. In other words, we predict the employment share in large-scale coal-based industries (X_{pred}) that can be explained by the spatial proximity to coalfields (Z). Recall that variation in the original variable X (large-scale coal-based industries) is not only due to the spatial proximity of coalfields (Z), but also to possible reverse effects of personality traits (Y). Variation in X_{pred}, however, is only due to variation in Z or, in more straightforward terms, X_{pred} is the coal-related share in large-scale coal-based industries in the regions.

In the second step of the IV analysis, this coal related share in large-scale coal-based industries (X_{pred}) is used to explain the regional personality traits and regional well-being (Y). Because variation in X_{pred} is due only to spatial proximity to the instrument (minimum distance to nearest coalfield (Z)), we can rule out endogeneity between X_{pred} and Y. In that sense, we can be surer of the directionality of a possible relationship between X and Y. If the regression coefficient of X_{pred} is significantly different to zero, we can be surer that the presence of large-scale coal-based industries affects regional psychological factors (at least the coal-based part), and not the other way around.

Historical Control Variables

While an instrumental variable can clarify the direction of effects, control variables can help rule out alternative explanations for observed effects. To control for additional historical factors potentially affecting the psychological make-up and cultural characteristics of the regions, we considered a number of historical control variables (Oishi, 2014; Rentfrow et al., 2008).

Energy supply

We considered two additional indicators of historical energy supply, which potentially influenced early economic activities that could persist until today and potentially shape the psychological make-up of regions. First, industrialization began earlier than the invention of the steam engine. It is thus possible that the seeds of today's industrial structure were already set before the age of steam. Besides horses, the most important power source in medieval times came from water mills. Thus, the *number of water mills* in British regions around 1800 is taken from Kanefsky (1979), who builds his data on very detailed historical county maps that show the location of water mills. The number of water mills in a region serves as a control variable in the regressions.

Second, steam engines already provided power for production processes before the peak of the Industrial Revolution. Much deserved praise is given to Boulton and Watt for the development of the double-acting steam engine in 1782, but early less efficient and less powerful precursors to the Boulton and Watt engine, such as the Savery and Newcomen engine, were applied in mining and other industries from the beginning of the 18th century onwards. To account for such early patterns of steam use, we considered a variable that measures the number of *erected steam engines up to 1733*. This variable also makes it possible to check whether it was this early spread of steam engines during the early days of the Industrial Revolution, or whether it was indeed the presence of large-scale steam-powered industries during the peak of the Industrial Revolution (and the related psychosocial and economic consequences for local populations), that enduringly affected the local populations and thus the psychological make-up of regions.

The data on steam engines are taken from Kanefsky (1979) who compiled a list of all erected steam engines in the 18th and 19th centuries based on a broad range of historical documents and earlier work in this area. If a steam engine was used in a factory, mine, or workshop, this is counted as an erected steam engine. Detailed information is available on where the engine was used and for what purpose. For this research we rely on the number of erected steam engines in a county between 1700 and 1733. The coverage of this list is considered to be excellent (Nuvolari, Verspagen, & Von Tunzelmann, 2011) but this variable also has some limitations; for example, if an engine broke after a year or two of service, and the engine was replaced, this would count as two steam engines.

Historical education level

Education might have shaped the local culture in the past (e.g., Stuetzer et al., 2016). To account for this factor, we considered the *school attendance rate in 1851*. In this year the first Census of Education was conducted, the results of which were initially published in the original Census of Population report. To derive a regional school attendance rate, the Great

Britain Historical GIS project combined the attendance numbers with the actual number of children aged 5-14; we rely on their published data. Note that in 1851 school attendance was not compulsory, so the data reflect the conscious decision of people to send their children to school. Data for the County of Rhonnda were missing and thus imputed by taking the averages of neighboring regions. This work is based on data provided through www.VisionofBritain.org.uk and uses statistical material, which is copyright of the Great Britain Historical GIS Project, Humphrey Southall, and the University of Portsmouth.

Historical wealth

The local culture could be a consequence of regional differences in historical wealth so we considered a proxy measure of medieval wealth, namely *local church income streams in 1291*. In 1291, Pope Nicholas IV granted the English king with a "tithe" (tax) upon spiritualties and temporalities of the church to finance the proposed crusade to the Holy Land. Spiritualties are church income streams from religious sources (such as church services) and the tithe that the local populace had to pay. In contrast, temporalities were income streams from the properties and possessions of the church (e.g., a monastery owned land and derived income from it). It is clear that these income streams strongly depend on the strength of the local economy. Thus, the church-income data provide an excellent source of medieval wealth. The data on local church income streams are taken from Campbell (2008), who provides total tax values in Pounds for U.K. dioceses and then redistricted to spatial units in this dataset. Note that Campbell (2008) strongly suggests using only the carefully edited data on spiritualties (excluding temporalities). We thus use a measure where the total value of spiritualties was normalized by the area of the region providing a measure of income per square kilometer.

Another historical indicator for wealth is the presence of ports. In Great Britain, ports were hubs for domestic trade and also for trade with Continental Europe. Contact with other parts of the world might influence personality traits such as Openness. We thus included a

dummy variable indicating the regional presence of a *port in the middle ages* (around 1290). The data regarding the location of ports were taken from Campbell (2008).

Geology and climate

Research indicates that geology and climate can shape local cultures (Oishi, 2014), via, for example, local differences in agrarian productivity (Talhelm et al., 2014) or in historical trade (Greif, 1994); so we considered the following control variables. Following Falck, Heblich, Lameli, and Südekum (2012), we assessed the soil quality of a region with a dummy variable indicating any limits to agricultural use (e.g., gravelly, lithic, or sodic soil). We additionally considered the *soil depth to rocks*; larger values should indicate more suitable soil for agriculture and thus pre-industrial wealth. These data are taken from the European Soil Project (Panagos, Van Liedekerke, Jones, & Montanarella, 2012; 1km by 1km raster data) and the data generation procedure is described in Combes, Duranton, Gobillon, and Roux (2010). We also considered the *ruggedness* of a region. Historical trade routes connected economic centers but avoided difficult terrain such as mountains. Thus, the ruggedness of a region is an acceptable indicator for terrain difficulty, which can also be understood as a proxy of low regional pre-industrialization wealth generated by trade (Greif, 1994). Following others, we measure the ruggedness of a region by the difference between the maximum and minimum elevation (Falck et al., 2011). Data on terrain differences also come from the European Soil Project.

Regarding climate, we use the *mean July temperature in 1960-1990* as a reference period. Higher temperatures prolong the growing season, which relates to richer harvests and ultimately higher pre-industrial wealth in a region. Moreover, research indicates that people living in warmer regions are more emotionally expressive (which is also known as the Montesquieu hypothesis; Pennebaker, Rimé, & Blankenship, 1996; see also van Lange, Rinderu, & Bushman, in press). The temperature data are from the Met U.K. Office (5km grid files). Note that the data for regional soil quality and climate are current data and we assume

that regional variation in soil quality and climate has not dramatically changed over the past two centuries (see for a similar approach Falck et al., 2011).

Population density

More densely populated regions usually differed in their cultural, social, and economic trajectories from more rural areas (Oishi, 2014). We thus considered the local population density (measured in the 1811 census). The regional variation in population density in 1811 remained relatively stable until today, which underscores the long-term effects of the agglomeration processes and the changing population map during the Industrial Revolution. The region level stability coefficient (correlation between population density in 1811 and 2011) is $r = .68$ ($p < .001$).

Demographic Control Variables

To permit analyses controlling for demographic variables, we obtained the regional percentage of females, of young people (0-24 years), of black people, and of Asian people from the 2011 U.K. Census.

Economic Hardship

To test economic hardship as a potential mediator between the historical concentration of large-scale industries and today's personality and well-being patterns, we considered two indicators. First, we used the regional unemployment rate in 2001. The data were taken from the 2001 Census. Using 2001 data instead of any other recent year is justified because the variation of this structural variable between regions does not change much over time. The regions with high unemployment in 2001 are essentially the same as in 2011 or in 1981.

Second, we considered the employment growth between 1931-2011. The variable is computed as the percentage change in the number of employees between 1931 and 2011 in the region. This measure is somewhat different from the simple unemployment rate because it captures the *long-term* economic development of regions. The higher the employment growth

in a region, the more the regional economy is expanding, signaling economic well-being. Conversely, a lower (and sometimes even negative) employment growth signals economic hardship in the region. Note that, employment growth is the most often used indicator of regional economic performance that can be compared across regional, national, and temporal contexts (see Stuetzer, et al., 2017 for more information). The 2011 data are taken from the 2011 U.K. Census. The 1931 data are taken from the 1931 British Census which has been digitized and made available for research by the Great Britain Historical GIS Project.

Table S2 in the online Supplemental Material provides the zero-order correlations among all variables used in this study.

Results

Effects of Large-Scale Coal-Based Industries on Regional Levels of Psychological Adversity

We first ran a series of hierarchical regression analyses to predict the regional differences of each of the personality factors (Big Five personality traits, 10 personality sub-facets) and the two conventional well-being indicators (life satisfaction and life expectancy). The independent variables were the historical employment shares in the different economic sectors (step 1 in the regression) and, in addition, the historical conditions regarding energy supply, education, wealth, geology, climate, and population density (step 2 in the regression). The results for the effect of our main predictor variable, the *employment share in large-scale coal-based industries*, are summarized in Table 1 (see Tables S3-S19 for the detailed results).

Regarding the Big Five traits, we found the local *employment share in large-scale coal-based industries* to have a negative effect on region level *Conscientiousness* (step 1: ß = -.35, $p < .001$; step 2: ß = -.26, $p < .01$) and a positive effect on region level *Neuroticism* (step 1: ß = .37, $p < .001$; step 2: ß = .33, $p < .01$). The full regression models (step 2) explained 29% of the regional variance in *Conscientiousness* and 20% of the regional variance in *Neuroticism*.

Regarding the 10 personality sub-facets, we found the local *employment share in large-scale coal-based industries* to have a negative effect on region level *order (C1)* (step 1: ß = -.49, $p < .001$; step 2: ß = -.35, $p < .001$) and *activity (E2)* (step 1: ß = -.36, $p < .001$; step 2: ß = -.24, $p < .05$), and a positive effect on *anxiety (N1)* (step 1: ß = .31, $p < .01$; step 2: ß = .31, $p < .01$) and *depression (N2)* (step 1: ß = .38, $p < .001$; step 2: ß = .31, $p < .01$). The *employment share in large-scale coal-based industries* also showed a (negative) effect on *self-discipline (C2)*, but only in the first step of the regression model (step 1: ß = -.25, $p < .01$; step 2: ß = -.19, n.s.). The full regression model (step 2) explained 38% in the regional variance of *order (C1)*, 18% in the regional variance of *activity (E2)*, 12% in the regional variance of *anxiety (N1)*, 32% in the regional variance of *depression (N2),* and 28% in the regional variance of *self-discipline* (*C2*) (with the non-significant effect of *employment share in large-scale coal-based industries*). Hence, taken together, these results supported the "psychological adversity" Hypothesis of detrimental long-term effects of the Industrial Revolution.

Regarding well-being in the region, the local *employment share in large-scale coal-based industries* had a negative effect on both indicators: *life satisfaction* (step 1: ß = -.35, $p < .001$; step 2: ß = -.29, $p < .01$) and *life expectancy* (step 1: ß = -.57, $p < .001$; step 2: ß = -.50, $p < .001$). The full regression model (step 2) explained 35% in the regional variance of *life satisfaction* and 45% in the regional variance of life expectancy.

To control for current socio-demographic characteristics of regions, which are not related to the historical industry structure, we ran additional regression models with *employment share in large-scale coal-based industries* as predictor and the personality traits (Big Five and 10 sub-facets) and the two well-being indicators *life satisfaction* and *life expectancy* as dependent variables. These socio-demographics were the regional percentage of females, of young people (0-24 years), of black people, and of Asian people (note that these regional factors did show significant correlations with the employment share in large-scale

coal-based industries). The effects of the *employment share in large-scale coal-based industries* on *Conscientiousness*, *Neuroticism*, *order (C1), activity (E2), anxiety (N1), depression (N2), life satisfaction, and life expectancy* remained significant (as shown in Table 1).

Instrumental Variable Analysis

To address the potential endogeneity in these results (described earlier), and to clarify the direction of the observed significant effects of the employment in large-scale coal-based industries on regional personality and well-being differences, we employed the instrumental variables technique using *distance to nearest coalfield* as an exogenous instrument (Angrist, Imbens, & Rubin, 1996). We employed the Huber-White procedure to account for heteroskedasticity. Above, we have described the general IV approach but we left out one complicating detail: Other factors besides coal might affect the establishment and concentration of large-scale coal-based industries during the Industrial Revolution. Therefore, we control for alternative explanations for the regional concentration of large-scale coal-based industries. These control variables are the number of watermills around 1800 and the population density in 1811. The regional presence of watermills could have influenced the location decisions of firms in large-scale industries because watermills indicate early energy supply, which was important for industries such as textiles and metal manufacturing (Kanefsky, 1979; Nuvolari et al., 2011). Population density can influence the location decisions of large-scale industries because more densely populated regions provide a large customer base and a potential source of labor (Crafts & Mulatu, 2006). High regional population density and high availability of workforce also contribute to the flow of ideas ultimately fostering innovation (Glaeser & Gottlieb, 2009), which in turn can attract large-scale industries. We considered the local population density measured in the 1811 census. The results are depicted in Table 2.

The first stage of an IV analyses predicts the *employment in large-scale coal-based industries* by the exogenous instrument, *distance to nearest coalfield*. Note that the first-stage F statistic is well above 10 – a threshold indicating the relevance of the exogenous instrument (Staiger & Stock, 1997). This finding is consistent with our general assumption that coal-based large-scale industries were located in certain regions that showed spatial proximity to coalfields. In the second stage of the IV analysis, that part of the variation in the *employment share in large-scale coal-based industries* that can be explained by spatial proximity to coalfields (after controlling for alternative explanatory factors), is used for the prediction of the regional personality characteristics. We found significant effects for *Conscientiousness* and *Neuroticism* among the Big Five, for the sub-facets of Conscientiousness (*order*), Neuroticism (*anxiety* and *depression*), and Extraversion (*activity*), and for *life expectancy*.

Note that we did not use all variation in the *employment share in large-scale industries* in explaining variation in the Big Five traits because these industries might have located to certain regions because particular kinds of people or personalities were known to live there (endogeneity). Instead we used only that part of the variation in coal-based large-scale industries that was attributable to the proximity to coalfields. The significant coefficient of the employment share in large-scale coal-based industries then indicates that the relationship runs from historic coal-based industry structure towards regional personality make-up and well-being aspects (*life expectancy*), and not the other way around (Angrist et al., 1996). Thus, the historical industry structure shapes the psychological and well-being features of the local populations. Hence, we received further support for the "psychological adversity" Hypothesis, which states that regional personality and well-being have a common source—historical industry patterns.

Effects of Other Historical Predictor Variables on Regional Personality and Well-Being

We also examined the effects of the other historical predictor variables to shed further light on the historical roots of today's personality and well-being differences. However, we

had no adequate instrumental variables for these additional historical factors, so we were not able to study any causal relationships here. The results for the effects of the other historical predictors are summarized in Table 3 (see Tables S3-S19 for the detailed results). What stand out, first, are the effects of e*mployment in agriculture in 1813-1820*, which also indicate a relatively "negative" psychological pattern in the current psychological make-up in the regions that had a higher share in agriculture around 200 years ago. We found positive effects on *Neuroticism*, *anxiety (N1)*, *depression (N2)* and negative effects on *order (C1)* and *life satisfaction* and *life expectancy*. This set of findings is consistent with our assumptions on selective migration patterns, according to which rural regions were hit first by major hardship, which might have increased their overall psychological adversity due to socialization effects, and then these rural regions were hit again by the departure (migration to the coal regions) of those people lowest in psychological adversity in these rural regions.

Second, the effects of *watermills* also delivered a rather consistent picture, indicating a relatively "positive" psychological pattern today. We found positive effects on *Conscientiousness*, *order (C1)*, *self-discipline (C2)*, and *life satisfaction* and *life expectancy*; and a negative effect on *depression (N2)*. It seems that those regions that enjoyed an early economic prosperity, indicated by a concentration of watermills as a major pre-industrialization energy source, but that did not belong to the coal-based, steam-powered centers of the Industrial Revolution (with the detrimental effects on the local personality and well-being levels in these regions), are today more on the "bright side of life". We can only speculate, but one reason for this pattern could be an historical imprint of a local "watermills culture" during the Industrial Revolution, characterized by small-scale manufacturing with less division of labor and more self-initiative than that found in the steam-based centers. Another explanation could be that water mills indicate proximity to water, which offer benefits such as hygiene and beautiful landscapes.

Another interesting possible explanation for this observed positive effect of watermills in our analysis comes from Talhelm et al.'s (2014) study on regional psychological differences in China. One can ask whether watermill culture in industrialized nations might have some parallels to wheat-farming culture in northern China. Wheat farming was a relatively independent activity, as opposed to rice farming, which required farmers to coordinate their water use and exchange labor. In China, people in wheat areas show more independence and are more likely to assert individual initiative and control over the environment (Talhelm, 2015). In contrast, coal industries may share some social style characteristics in common with rice-farming cultures. The tight social norms of rice cultures encourage a social style that emphasizes fitting in and obedience to elders, which studies have found is more common in U.S. working-class communities. However, one dissimilarity between coal industries and rice farming is that rice farms tended to be smaller and have more direct farmer control than wheat farms (Talhelm, 2015). This difference could explain the impression that collective agriculture during the Cultural Revolution took off more in wheat-farming northern China than in rice-farming southern China, as well as the fact that the rice areas of China have thrived with import-export trade under China's Reform and Opening. In that sense, rice cultures emphasize fitting social norms, but they also share characteristics of the idealized American small business owner culture.

Third, while the effects of *population density in 1811* showed a mixed picture, we find it interesting that those regions with higher historical education levels (*school attendance rate in 1851*) are today lower in *Neuroticism* and higher in *Extraversion* and *ideas* (O2), which might indicate a certain productive creativity in these regions. Those regions that had natural limitations to agricultural use are today higher in *Extraversion, Openness, aesthetics (O1), and ideas (O2)*, which again might indicate a certain productive creativity in these regions.

Furthermore, those regions with higher medieval wealth (*church income in 1291*) show lower levels in *Agreeableness* today. Low Agreeableness is associated with competition

and Machiavellianism (Paulhus & Williams, 2002), so perhaps these regions have cultivated a certain business-oriented culture that has persisted until today.

Mechanisms behind the Effect of the Historical Concentration of Large-Scale Industries on Regional Personality and Well-being Factors

What are the mechanisms behind the effects of large-scale industries on regional personality and well-being? In Figure 1 we attempted to describe how mechanisms of selections and socialization could unfold over time, but in the present study, due to limitations in data availability, we can only address a small selection of the potential mechanisms at work. Specifically, we focus on recent migration patterns and the detrimental effects of recent economic hardship.

Recent Migration Patterns

We investigated recent migration patterns, in the *Post-Steam period*, as a potential explanation for our findings. To this end, we utilized migration information contained in the BBC Lab U.K. personality dataset. The questionnaire not only asked participants to indicate the location of their current residence (current postal code) but also the postal code of the place where they grew up. Of the n = 156,562 who grew up in an old coal region, n = 130,240 (83.19%) still lived in an old coal region today, and n = 26,322 (16.81%) had left the old coal regions. Hence, it was possible for us to compare "leavers" (respondents who grew up in an old coal region and moved to a region that is not part of an old coal region) with "stayers" (those who remained in the old coal regions), with respect to personality traits and well-being.

Table 4 presents the results of these group comparisons. Regarding the Big Five, we indeed found the "stayers" to score higher in *Neuroticism*, and lower in *Conscientiousness* and *Openness*. The effects, however, were rather small (Cohen's d between ±.08 and ±.13). Regarding the sub-facets, the "stayers" scored lower in *activity*, *compliance*, *order*, *self-discipline*, *aesthetics*, and *ideas*, and higher in *altruism*, *anxiety*, and *depression*. Again, the effects were rather small (Cohen's d between ±.03 and ±.14). Finally, with respect to well-

being, the "stayers" reported lower *life satisfaction* (Cohen's *d* of .10). We also checked for group differences between those movers who moved out of coal regions and those who moved into coal regions. With respect to the Big Five traits, we found significant group differences in four Big Five traits: Movers who moved into coal regions scored significantly lower in *Conscientiousness*, *Extraversion*, and *Openness*, and higher in *Neuroticism* (with Cohen's *d* between ±.04 and ±.06). We found similar group differences in the sub-facets, with higher scores in traits indicative of adversity in those who had moved into coal regions, compared with those who had left coal regions. However, we found no significant group difference in *life satisfaction*.

Taking these results on systematic migration together, there is indeed some evidence pointing to a selective migration pattern with an outflow of people low on psychological adversity, and an inflow of people high on psychological adversity. However, these data do not distinguish, for example, between the possibility that the people who left the coal regions already were lower on psychological adversity before they had left, or whether their psychological adversity levels dropped after they left the coal regions. Given that personality is relatively stable, the first option seems more likely.

The pattern of findings, with the people who moved into the former coal regions being higher on psychological adversity than those who moved out of them, suggests that moving itself might not be a sign of low psychological adversity; perhaps, moving to a new region is a sign of low psychological adversity only when that move is motivated by harsh economic conditions. Alternatively, the pattern of findings could be explained by a general trend of people moving to areas populated by people with similar personalities, such that the leavers low on psychological adversity leave for areas populated by other people low on psychological adversity and the people high on psychological adversity move into the old coal regions to fit in with the people high on psychological adversity who already live there (Bleidorn et al., 2016). Unfortunately, we do not have the data to test this possibility directly.

To approach the question of how strongly such recent migration patterns might have shaped the local psychological patterns empirically, we re-ran our regressions summarized in Table 1 with the regional personality levels calculated only from those respondents who did not migrate (i.e., those who stayed in the region where they grew up). Hence, these regional personality measures should be relatively unaffected by recent selective migration patterns. We found the same pattern of effects of large-scale industries on regional Big Five traits and their sub-facets, but the effects were somewhat smaller (but in almost all cases still significant). This analysis provides further support for the idea that recent selective migration is indeed a relevant mechanism (because the effect of large-scale industries is smaller in this additional analysis), but we have no reason to assume that such recent selective migration is the only mechanism (because the effect of large-scale industries is still there in these regressions). However, we reiterate that we cannot address earlier, historical migration patterns in our empirical analysis.

Mediation Models with Economic Hardship as Mediator

In addition to recent selective migration, another potential mechanism is recent economic hardship. As noted earlier, many old industrial regions have been facing significant economic hardship for a long time, which could have contributed to the relatively adverse personality and well-being levels that we identified in the regions. To model this potential mechanism, we tested the regional *unemployment rate* (of 2001) and regional *employment growth between 1931 and 2011* as mediators between the historical *employment share in large-scale coal-based industries* during the Industrial Revolution on the one side, and today's regional personality make-up and well-being on the other. We considered only those traits and well-being indicators that were significantly predicted by the historical *employment share in large-scale coal-based industries* (Table 1, see also Table S3-S19) – that is, the direct effect that might be mediated by economic hardship in the region.

Figure 2 illustrates the mediation model including the relevant Big Five traits, and Figure 3 shows the corresponding mediation model including the relevant sub-facets. In both models, regional economic hardship was predicted by the *large-scale coal-based industries* during the Industrial Revolution (*unemployment rate 2001*: ß = .23, $p < .05$; *employment growth 1931-2011*: ß = -.21, $p < .001$), reflecting the established fact that the old industrial regions have suffered economically in recent decades more than other regions have. Regarding relevant Big Five traits (Figure 2), recent economic hardship measured via the *unemployment rate in 2001* showed negative effects on region level *Conscientiousness* (ß = -.48, $p < .001$), *life satisfaction* (ß = -.79, $p < .001$), and *life expectancy* (ß = -.78, $p < .001$), and positive effects on region level *Neuroticism* (ß = .49, $p < .001$). In addition, *employment growth 1931-2011* had a positive effect on region level *Conscientiousness* (ß = .23, $p < .01$).

Regarding relevant sub-facets (Figure 3), recent economic hardship measured via the *unemployment rate in 2001* showed negative effects on region level *order* (ß = -.55, $p < .001$) and *activity* (ß = -.42, $p < .001$), and positive effects on region level *anxiety* (ß = .38, $p < .001$) and *depression* (ß = .61, $p < .001$). In addition, *employment growth 1931-2011* had a positive effect on region level *order* (ß = .27, $p < .001$). With respect to regional well-being, recent economic hardship measured via the *unemployment rate in 2001* again showed negative effects on region level *life satisfaction* (ß = -.79, $p < .001$) and *life expectancy* (ß = -.78, $p < .001$).

The test for the indirect effects of *large-scale coal-based industries* during the steam age on personality traits and well-being via recent economic hardship revealed a significant mediation effect in both models. Specifically, in Figure 2 bootstrap mediation testing (5,000 bootstrap resamples; 95% bias-corrected confidence interval) estimated a significant indirect effect of *large-scale coal-based industries* via *unemployment rate 2001* on *Conscientiousness* of ß = -.11 (95%CI = -.19 and -.05; $p < .05$), on *Neuroticism* of ß = .11 (95%CI = .04 and .20; $p < .05$), on *life satisfaction* of ß = -.18 (95%CI = -.28 and -.08; $p < .05$), and on *life*

expectancy of ß = -.18 (95%CI = -.27 and -.08; p < .05). The respective significant indirect effect via *employment growth 1931-2011* on *Conscientiousness* was ß = -.07 (95%CI = -.13 and -.03; p < .05).

In Figure 3, the same mediation test estimated a significant indirect effect *of large-scale coal-based industries* via *unemployment rate 2001* on *order* (C1) of ß = -.12 (95%CI = -.20 and -.06; p < .05), on *anxiety* (N1) of ß = .08 (95%CI = .03 and .18; p < .05), on *depression* (N2) of ß = .14 (95%CI = .06 and .23; p < .05), on *activity* (E2) of ß = -.09 (95%CI = -.17 and -.04; p < .05), on *life satisfaction* of ß = -.18 (95%CI = -.28 and -.08; p < .05), and on *life expectancy* of ß = -.18 (95%CI = -.27 and -.08; p < .05). The respective significant indirect effect via *employment growth 1931-2011* on *order* (C1) was ß = -.08 (95%CI = -.14 and -.03; p < .05).

Taken together, these mediation results are consistent with the assumption that persistent economic hardship in the old industrial regions might have contributed to their current levels of psychological adversity. Like our migration analyses, these mediation analyses cannot exactly determine how powerful these single shaping processes are (e.g., because there might be a great variety of interacting mechanisms at play, as assumed in Figure 1). The mediation analyses provide at least some insights into possible causal mechanisms, but we should stress that the actual pattern of relevant mechanisms unfolding over two centuries are likely to be highly complex and dynamic. For example, we can expect that selective migration and persistent economic hardship might also interact with each other. For example, economic hardship might be a major driver of selective migration (e.g., an outflow of individuals lower in psychological adversity), and such selective migration, in turn, could be a major driver of the persistence of economic hardship (e.g., due to an outflow of individuals low on psychological adversity who could have helped to counter the economic decline).

So far, the results of our study in England and Wales delivered robust support for the assumption that a historical concentration of large-scale industries had a negative effect on today's regional personality traits and well-being (with recent selective migration and persistent economic hardship as likely mechanisms, in addition to others that we did not test here). But would this central finding on the link between large-scale industries and psychological adversity also generalize to other countries with a similar industrial history? To find out, we conducted a (smaller) robustness check using data from the U.S.

Robustness Check using Data from the U.S.

Like the U.K., the U.S. was also heavily based on coal and steam-intensive large industries between the Industrial Revolution and the dawn of the new modern economy. Equivalent historical data from the U.S. are not readily available, so we could not repeat exactly the same analyses as those undertaken for England and Wales. Thus, the additional analysis of the U.S. case is limited in terms of the wealth of historical variables available and the number of regions.

Regional level. We compare U.S. regions at the level of States. The reason for using the State level, rather than a more fine-grained level such as counties, is that State was the lowest level at which our main variable, employment in large-scale coal-based industries, was available. Note that regional analyses in psychology are often conducted at the State level (e.g., Rentfrow et al., 2008).

Personality data. We used the well-established personality data from the Gosling-Potter Internet project (see Rentfrow et al., 2008), which is an ongoing study collecting Big Five data via a noncommercial Internet website, which can be reached via several channels (e.g., search engines, unsolicited links on other webpages). People from all countries can voluntarily participate in this study by completing a questionnaire on socio-demographic variables, personality traits, and state of residence. As an incentive, participants receive personality feedback based on their responses. The dataset has been widely used in studies on

regional personality (e.g., Obschonka, Schmitt-Rodermund, Silbereisen, Gosling, & Potter, 2013; Rentfrow et al., 2013). Here we analyze the recent U.S. version of this dataset with N = 3,457,270 respondents living in the U.S. (M = 67,790 respondents per State, SD = 67,068, Min = 6,048, Max = 350,411).

Well-being data

Well-being data come from the Gallup (2015) State Well-Being Rankings. These data are based on a survey, which was returned by approximately 2.3 million U.S. respondents. Among other things, the respondents stated their satisfaction in several domains such as purpose (liking what you do each day), financial satisfaction (managing your economic life to reduce stress and increase security), and physical satisfaction (having good health and enough energy to get things done daily). Based on these domains, Gallup computes the overall *Gallup Well-Being Index* (Gallup-Healthways Well-Being Index; see also Deaton, 2008). Other surveys have gathered data on regional happiness and well-being – most notably the World Value Survey; however, data from these surveys are often used for inter-country comparison and were not used for this analysis because the small sample size prohibits regional analyses (e.g., the sample size of 2,000 respondents results in approximately 10 observations for sparsely populated U.S. states such as Nebraska).

Historical industry structure. Data on coal-based large-scale industries were taken from the 1900 U.S. Census and consist of the combined employment share in iron, and steel as well as clay, glass, and stone products. Data on the employment in coal mining were not available from the 1900 U.S. Census (U.S. Census Office, 1901a). We thus used the data from the U.S. 1910 Census (U.S. Census Office, 1913). Note that the above choices of industries and time resemble the U.K. case with three exceptions.

First, employment data in the U.S. refer to the beginning of the 20th century, but the U.K. data use the beginning of the 19th century. U.S. census data are available from the 19th century but the geographical coverage of these data would be strongly restricted because the

U.S. expanded westwards in the 19th century. Moreover, the 20th century data are arguably a good proxy for the 19th century data, with economic-geography models pointing to the persistence in location of many manufacturing industries (Crafts & Mulatu, 2006; Krugman, 1991). Perloff (1960) reports that the manufacturing belt, which was the center of the industrialization in the U.S., still contained around two thirds of all U.S. employment in manufacturing in 1960. Since then this number has been shrinking, turning the manufacturing belt into today's Rust Belt. With one major exception, which we discuss below, this persistence in structures of many industries is a result of the persistence in the determinants of those industries (e.g., coal resources, market size, knowledge; Crafts & Mulatu, 2005, 2006).

Second, in the U.K., case employment data were available for the industry category, "bricks and pottery," which was slightly different from the closest U.S. industry category, "clay, glass, and stone products."

Third, we did not use the employment share in textiles in the U.S. case in 1900. The reason for doing so stems from the persistence argument made above. The textile industry is the one major exception to the persistence in industry structures in the U.S. case. From the 18th century until the middle of the 19th century the textile industry was concentrated in the North East, as were most other manufacturing industries because of the availability of coal as a power source and because of the market size. So if we had used data from this time period, we would have had to include the textile industry in our list of large-scale coal-based industries. However, from 1870 onwards many cotton mills were founded in the south of the U.S., such as North Carolina and Georgia, because of the availability of cheap labor and cotton. The initial link between the textile industry and cheap coal as an energy source from the coalfields weakened in this time period due to expansion of the railway system, which made the transport of coal from the coalfields economically feasible (Andrews, 1987). Another reason for the weakening link to coalfields was the advancement of water wheels to turbines, which used waterpower more efficiently, allowing smaller-scale cotton mills to be

run without coal. In that sense, the location of the textile industry around 1900 was more strongly influenced by the availability of cheap labor and distance to agricultural regions suitable for cotton than by the distance to coalfields. Thus, we refrain from including textiles as a coal-based large-scale industry around 1900.

Coalfields as instrumental variable

Mirroring the instrumental variable approach in the U.K., we digitized a map showing the historical coalfields for the contiguous U.S. states in 1909 (Tarr & McCurry, 1910). Based on this map, we computed the minimum distance of each State to the nearest coalfield. Note that the map shows only the coalfields in the contiguous U.S. excluding Alaska and Hawaii. However, we can conclude from geological surveys that there are no coal deposits in Hawaii and that there are coal deposits in Alaska. Accordingly, the distances for both States were calculated.

Population density. As in the U.K. regression, we used population density as a control variable. The data relate to the year 1900 (U.S. Census Office, 1901b).

Correlations. Table 5 presents correlations among the variables at the U.S. state level. Following Rentfrow et al., (2008), we considered region-level correlations in this dataset in the order of .10 as ‘‘small,’ of .20 as ‘‘medium,’’ and of .30 or greater as ‘‘large.’’ There was a small correlation between *coalfields* and the *employment share in large-scale coal-based industries* (r = -.11, ns). This link is much weaker than in the U.K. analysis. One reason for this difference is probably that industrialization took place in the U.S. after the rise of railways. The railway networks lowered transportation costs, which weakened the connection between coal and coal-based industries (Glaeser et al., 2015). Thus coal-based large-scale industries might have located in some proximity to coalfields but not as close as in the U.K. case. However, there is a large correlation between *population density* and the employment share in *large-scale coal-based industries* (r = .71, p < .001). This finding is consistent with theoretical models and observations that predict market size as an important factor for

industry location (Crafts & Mulatu, 2005; Krugman, 1991). This link contrasts with the U.K., where industrialization started much earlier and before the rise of the railway, arguably leading coal-based industries to locate very near to coalfields, which could then hardly be reversed.

Furthermore, there was a significant, large correlation between *distance to nearest coalfield* and *well-being* ($r = .38$, $p < .01$). *Distance to nearest coalfields* also showed small to medium correlations with personality traits that are associated with psychological adversity (*Neuroticism*: $r = -.16$, ns; *Conscientiousness*: $r = -.13$, ns; and *Extraversion:* $r = -.13$, ns). Hence, these correlations consistently point in the direction that old industrial regions in the U.S. have lower well-being and we also see some signs of a clustering of personality traits associated with psychological adversity in the old industrial regions.

When looking at the historical *employment share in large-scale coal-based industries* (our central study variable), we see a large and significant correlation with *Neuroticism* ($r = 0.48$, $p < .001$), *Conscientiousness* ($r = -0.47$, $p < .001$), and *Agreeableness* ($r = -0.47$, $p < .001$); and non-significant, small-to-medium correlations with *Extraversion* ($r = -0.17$, ns) and *Openness* ($r = 0.15$, ns). Taken together, these correlations suggest that personality traits associated with psychological adversity cluster in old industrial regions in the U.S. There was a weak to non-existent correlation with the *well-being* index, though ($r = -0.08$, ns).

Instrumental Variable Analysis

Table 6 presents the results of the IV-regression using the *distance to the nearest coalfield* as an instrument for the *employment in large-scale coal-based industries*. This IV regression replicates the U.K. analyses (Table 2) with the exception that in the U.S. case we could not consider data on the number of watermills as an energy source because the relevant watermill data were not available. The results of the first stage of the analyses show that population density is a strong predictor of the employment share in large-scale coal-based industries. Controlling for population density, the first-stage results also show that the

instrumental variable (*distance to the nearest coalfield*) predicts the instrumented variable (*employment share in large-scale coal-based industries*) ($p < .01$). The first-stage F statistic is above 10, which indicates the suitability of the instrument (Staiger & Stock, 1997). The second-stage results show that the *employment share in large-scale coal-based industries* that is attributable to the exogenous factors (coalfields) predicts higher *Neuroticism* ($p < .01$) and less *well-being* ($p < .01$). Recall that the bivariate correlation of the employment share in large-scale coal-based industries was not significantly related to well-being. Thus, it appears that it is that part of the employment share in large-scale coal-based industries in particular, that is attributable to coal, that negatively impacts well-being. This IV regression with the U.S. data thus suggests that an effect of the coal-based historical industry structure on Neuroticism and lower well-being is driving the region level correlation between the historical concentration of large-scale industries on the one side, and Neuroticism and lower well-being on the other. In other words, the central result from our main study, which points to an adverse psychological heritage of coal-based large-scale industries in the U.K., was largely replicated in this additional analysis.

Discussion

Our study examined whether long-term exposure to massive industrialization in a region leaves a lasting psychological imprint that reflects and conserves the adversity associated with the perils of industrialization. More specifically, our study addressed whether indicators of *psychological* adversity (assessed conventionally, in terms of well-being indicators and less conventionally, in terms of related personality traits) would cluster in old, coal-based industrial regions. Our focal analyses examined this question at a relatively fine-grained spatial level in England/Wales and controlled for several alternative explanatory factors. We also studied potential mechanisms, thereby focusing on migration patterns and the role of persistent economic hardship. Finally, we undertook a robustness check, examining

the links between historical industry structure, historical coalfields, and markers of psychological adversity in another country (the U.S.), albeit at a coarser level of detail.

Our main analysis in the U.K., the "motherland" of the Industrial Revolution, and the robustness test in the U.S. delivered a relatively consistent picture: The historical concentration of large-scale industries, which was associated with local coal resources, has left a sustained psychological heritage that remains "under the skin" in these regions, in terms of a local personality structure that is associated with psychological adversity, as measured in terms of well-being and associated personality traits. In the U.K., the negative effect of large-scale industries was particularly robust (when controlling for historical confounds and using distance to coalfields as an instrument) in the prediction of lower Conscientiousness and well-being (life expectancy) and higher Neuroticism. In the U.S. robustness check, we found a similar pattern for lower Conscientiousness and higher Neuroticism in terms of region-level correlations (in addition to a negative correlation between large-scale industries and Agreeableness, which we did not find in the main U.K. analysis). The instrumental variable regression in the U.S. analysis confirmed the negative effect of large-scale industries on Neuroticism, and also revealed a negative effect of large-scale industries on well-being.

Taken together, our results paint a relatively negative picture of the psychological heritage of coal. Similarly, negative down-stream consequences have been found in other domains such as economics, where the term the "curse of natural resources" is used (Sachs & Warner, 2001); in the modern economy, regions with natural resource wealth often achieve less economic growth than do other regions (Sachs & Warner, 2001). Our study, focusing on psychological adversity, points towards an additional mechanism through which natural resources like coal (and their exploitation and industrial use for steam-based production) may impede the progress and well-being of a region — through the shaping and clustering of regional personality differences. However, one should stress that while the massive historical industrialization of these regions was often based on (spatial proximity to) coal resources, it

was not necessarily the coal itself that created the local psychological climate; rather, it is likely that the stressful work and living conditions, together with selective migration patterns and lasting economic hardship, that lead to the collective psychological consequences observed in our study.

Our results have important implications for public health, epidemiological, and medical research and intervention strategies designed to tackle health at the regional level. The implications mirror those found for individual-level research on personality and well-being/health, in which one cannot develop a full understanding of a person's (or region's) well-being and health if one disregards personality factors (Bogg & Roberts, 2004, 2013; Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007; Roberts, Walton, & Bogg, 2005; Steel et al., 2008). The regional prevalence of traits related to psychological adversity should be understood as "personality trait marker" (Bogg & Roberts, 2013) of lower regional well-being and health levels. These regional personality levels, in turn, may have a long history reaching back to the foundations of our modern industrial world, as revealed by the present analysis. Moreover, and of relevance to public policy, it seems safe to assume that these regional personality differences are likely to show remarkable persistence into the future (Rentfrow et al., 2008), such that they will continue to shape and direct the well-being and health trajectories of these regions (e.g., more hardship with respect to well-being and health). Nevertheless, public policy should try to incorporate a proactive focus on personality traits and the mechanisms through which they affect well-being and health (for a discussion on individual-level implications see, for example, Bogg & Roberts, 2013 and Roberts et al., 2005). There is evidence that personality can be changed in health interventions, at least to a certain degree (Bogg & Roberts, 2013). So, research and public policy focusing on regional well-being and health should not only consider the current (visible) environmental and structural conditions of regions (e.g., as emphasized in research on natural disasters: Cutter et al., 2015), but also the historical trajectories of regions.

The long-term economic conditions of the old industrial regions have long been recognized. Here, we identified a previously hidden psychological pattern also found in these regions. Is it possible that these two long-term consequences of coal – the economic and psychological – reinforce and amplify each other? Our analyses suggest that the poor economic conditions may ultimately result in personality traits such as low Conscientiousness, high Neuroticism, low well-being, and low activity. Low Conscientiousness is associated with poor work performance (Barrick & Mount, 1991) and low Conscientiousness and high Neuroticism is associated with low job satisfaction (Judge, Erez, Bono, & Thoresen, 2002). Research further demonstrated that (low) Neuroticism and higher levels in proactive agency and self-evaluation traits such as self-esteem, self-efficacy, and internal locus of control are related to better work performance and life success in today's post-industrial societies (Audretsch, 2007; Judge, Heller, & Mount, 2003; Silbereisen & Chen, 2010). So, these old industrial regions may be caught in a vicious downward spiral, in which the prevalence of traits related to psychological adversity magnifies these regions' poor economic conditions, which in turn further increase the prevalence of adversity traits (e.g., via selective out-migration).

Our analyses have a number of limitations. First, while our studies established an empirical link between industrial history and today's regional personality and well-being factors, the exact mechanisms underlying the link are still not fully explored. This link is likely to reflect a complex chain of events, unfolding over two hundred years and it seems impossible to model all relevant mechanisms in a single study (at least at this point). However, our results offer some insight into the role of economic hardship and selective migration. Future research could, for example, test whether the severe work and living conditions experienced during the age of steam in the old industrial regions increased psychological adversity via severe air pollution. Research could test, for example, regional differences in historical mortality rates associated with lung diseases such as lung cancer.

Analytically, such studies could examine multiple mediation models that test very different mechanisms against each other, where the chronological ordering of the variables could be preserved to better reflect possible prospective effects.

Second, our study focused on the *negative* psychological imprint of coal. This might, however, not be the full story. We also think it is worth drawing attention to a potential upside of old industrial regions. Future research could examine whether there might also be certain long-term positive effects in these regions, perhaps those related to higher social capital such as trust, solidarity, and civic engagement (Putnam 2000). Certain social movements (e.g., working men's clubs: Thompson, 1966) and the many references to solidarity and companionship in the cultural life in these regions (the "you'll-never-walk-alone"—attitude, as championed in the famous anthem of Liverpool Football Club) would point in this direction. The enduring psychosocial and economic burdens in these regions might have produced a certain solidarity or resilient mentality, similar to that shown in response to economic hardship during major economic crises (e.g., the Great Depression in the U.S.) and resembling individual resilience to adversity (Elder, 1974/1999).

Third, although this was not the focus of our study, we also found some interesting effects of local agriculture during the Industrial Revolution on regional psychological adversity (Tables S3-S19). Several of these effects were similar to the detrimental effects of large-scale industries. However, our study cannot really answer questions regarding the source of these effects. One potential explanation could be that there are parallel, and in part interacting, processes in play for old high-coal-share and old high-agricultural-share regions. One such process could be the more recent economic/market marginalization that *both* types of regions might have been experiencing since the end of the age of steam. But, as noted above, more historical processes could also play a role: It was often people from rural regions (e.g., farmers and their families) who moved to the emerging industrial centers during the Industrial Revolution and the age of steam (Redford & Chaloner, 1976). So another potential

explanation could be selective migration with old agricultural regions first experiencing higher psychological adversity as a result of poor economic conditions and major hardship (socialization effects), and then having this regional increase in psychological adversity concentrated (and thus amplified) by the out-migration of the people with the least psychological adversity in these rural regions. Such a pattern, should it find empirical support, would underscore the far-reaching effects of the Industrial Revolution, influencing the psychological maps far beyond the industrial centers that powered the historical changes.

To conclude, our study conveys two central messages. First, hardship and adversity persists in old, coal-based industrial regions, not only in terms of tangible economic struggles but also in terms of a more "hidden" psychological heritage. The coal-based, industrialized centers, which were for many decades the economic powerhouses of industrialized nations like the U.K. and the U.S., experienced manifold miseries lasting up until the present day. These miseries range from historically severe work and living conditions to the vulnerability to major economic crises such as the Great Depression, the 1970's energy crisis, or the Great Recession (Obschonka et al., 2016), which drive further selective migration from these regions. Our study indicates, that on top of these visible miseries, one can often observe a clustering of personality traits and low levels of well-being, indicative of psychological adversity.

The second central message concerns important implications. Given that the old, coal-based industrial regions remain as major population centers today, the legacy of coal continues to affect the well-being of millions of people, thereby raising major challenges for public policy. Policymakers have already put a strong emphasis on the interplay between natural ecosystems and well-being in the past (e.g., the global Millennium Ecosystem Assessment project of the United Nations, which links ecosystems as dynamic functional units of the living and nonliving environments with human well-being: Reid et al., 2005); however, our study adds a new perspective by pointing to the nexus between natural

resources, industrial history, and regional personality differences associated with well-being and health behaviors. Despite the massive structural changes in these regions over the past decades, powered by large sums of public money (e.g., major funds from the European Union for the old industrial regions in Britain and Germany), the legacy of coal lives on, not only in the industrial museums but also in the psychological make-up and migration patterns of the people who live in those regions and beyond them.

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Table 1

Summary of Hierarchical Regression Analyses Estimating the Effect of Large-Scale Coal-Based Industries in 1813-1820 on Regional Differences in Psychological Factors (N = 111 Regions in England and Wales)

	Effect of Large-scale coal-based industries in 1813-1820	
Regional psychological factors	Controlled for: Other economic sectors in 1813 -1820	Controlled for: Other economic sectors in 1813-1820 and Historical energy supply, education, wealth, geology, climate, and population density
Big Five personality traits		
Conscientiousness (C)	-.35 *** (R^2 = .16)	-.26 ** (R^2 = .29)
Neuroticism (N)	.37 *** (R^2 = .15)	.33 ** (R^2 = .20)
Extraversion (E)	-.15 (R^2 = .07)	-.04 (R^2 = .13)
Agreeableness (A)	.11 (R^2 = .05)	-.01 (R^2 = .15)
Openness (O)	-.02 (R^2 = .06)	-.07 (R^2 = .26)
Big Five sub-facets		
order (C1)	-.49 *** (R^2 = .28)	-.35 *** (R^2 = .38)
self-discipline (C2)	-.25 ** (R^2 = .13)	-.19 (R^2 = .28)
anxiety (N1)	.31 ** (R^2 = .11)	.31 ** (R^2 = .12)
depression (N2)	.38 *** (R^2 = .15)	.31 ** (R^2 = .32)
assertiveness (E1)	-.05 (R^2 = .06)	.07 (R^2 = .11)
activity (E2)	-.36 *** (R^2 = .10)	-.24 * (R^2 = .18)
altruism (A1)	.16 (R^2 = .04)	.10 (R^2 = .06)
compliance (A2)	-.08 (R^2 = -.01)	-.18 (R^2 = .11)
aesthetics (O1)	-.05 (R^2 = .05)	-.08 (R^2 = .25)
ideas (O2)	-.01 (R^2 = .06)	-.05 (R^2 = .24)
Well-being		
Life satisfaction	-.35 *** (R^2 = .15)	-.29 ** (R^2 = .35)
Life expectancy	-.57 *** (R^2 = .30)	-.50 *** (R^2 = .45)

Note. Standardized effects are given. R^2 = Adjusted variance explained by the regression model in each step.
*p < .05. **p < .01. ***p < .001.

Table 2

Instrumental Variable Analysis Using Distance to Coalfields as Instrument for Large-Scale Coal-Based Industries (N = 111 Regions in England and Wales)

	First stage	Second stage							
	DV: Employment share in large-scale coal-based industries in 1813-1820	DV: Conscientious-ness	DV: Neuroticism	DV: *order* (C1)	DV: *anxiety* (N1)	DV: *depression* (N2)	DV: *activity* (E2)	DV: Life satisfaction	DV: Life expectancy
Distance to nearest coalfield	-.12 (.02) ***	–	–	–	–	–	–	–	–
Employment share in large-scale coal-based industries in 1813-1820	–	-.00 (.00) **	.00 (.00) **	-.00 (.00) ***	.00 (.00) *	.00 (.00) **	-.00 (.00) **	-.00 (.00)	-.09 (.02) ***
Number of watermills, around 1800	-.00 (.01)	.00 (.00) ***	-.00 (.00) *	.00 (.00) **	-.00 (.00)	-.00 (.00) ***	.00 (.00) *	.00 (.00) ***	.01 (.00) ***
Population density in 1811	.01 (.01)	-.00 (.00) ***	-.00 (.00)	-.00 (.00)	-.00 (.00)	.00 (.00)	.00 (.00)	-.00 (.00) **	-.00 (.00)
Constant	11.60 (1.95) ***	3.67 (.01) ***	2.97 (.01) ***	3.29 (.01) ***	2.96 (.01) ***	2.86 (.01) ***	3.48 (.01) ***	4.77 (.02) ***	81.13 (.17) ***
N	111	111	111	111	111	111	111	111	111
First-Stage F-Statistics	29.99	–	–	–	–	–	–	–	–

Note. Non-standardized coefficients are given. Robust standard errors in parentheses. First stage = Prediction of Employment share in large-scale coal-based industries in 1813-1820 by the instrumental variable. Second stage = Prediction of the outcome variables using the predicted values from the first stage instead of Employment share in large-scale coal-based industries.
*p < .05; **p < .01; *** p < .001

Table 3

Summary of the Effect of Other Historical Predictors Variables (N = 111 Regions in England and Wales)

	Other historical predictor variables											
Regional psychological factors	Services in 1813-1820	Agri-culture in 1813-1820	Watermills around 1800	Steam engines up to 1733	Population density 1811	Church income 1291	School attendance 1851	Port around 1290	Rugged-ness	Depth to rock	Limitat. agricult. use	Temp. July 1960-1990
Big Five personality traits												
Conscientiousness (C)	-.19	-.18	.25 **	.02	-.39 ***	.01	.01	.08	-.12	.10	-.10	.05
Neuroticism (N)	.22	.48 ***	-.11	-.01	.24 *	.16	-.31 **	-.09	-.24	.01	-.05	-.20
Extraversion (E)	.01	-.14	-.03	.00	.09	.05	.37 **	-.10	.14	-.05	.21 *	.13
Agreeableness (A)	-.11	-.17	.18	.02	-.36 **	-.30 *	-.04	.16	-.12	-.17	-.02	-.01
Openness (O)	.16	.04	.12	.04	.34 **	-.02	.17	.06	.31 *	-.13	.31 ***	.10
Big Five sub-facets												
order (C1)	-.30 **	-.29 **	.19 *	-.02	-.24 *	.08	.07	.07	-.03	.11	-.06	.17
self-discipline (C2)	-.17	-.15	.26 **	.03	-.44 ***	-.06	-.01	.11	-.15 *	.11	-.08	.00
anxiety (N1)	.24	.49 ***	-.05	.01	.15	.19	-.26 *	-.12	-.25	.08	-.11	-.22
depression (N2)	.19	.45 ***	-.22 *	-.05	.34 **	.10	-.33 **	-.07	-.21	-.05	.00	-.13
assertiveness (E1)	.02	-.20	-.04	.01	-.01	.04	.31 *	-.12	-.02	.04	.18	.05
activity (E2)	-.04	-.01	.08	-.01	.11	.18	.31 *	-.01	.33 *	-.11	.13	.21
altruism (A1)	-.09	-.07	.11	.04	-.26 *	-.19	-.03	.12	-.16	-.18	-.10	-00
compliance (A2)	-.04	-.26	.19	-.04	-.28 *	-.25	-.04	.21	.13	-.19	.07	.13
aesthetics (O1)	.07	.00	.14	.05	.37 **	.01	.23	.10	.23	-.13	.31 ***	.06
ideas (O2)	.21	.03	.11	.05	.28 *	.00	.13 *	.04	.43 **	-.09	.29 ***	.19
Well-being												
Life satisfaction	-.26 *	-.36 **	.30 ***	-.01	-.29 **	-.05	.33 **	.08	.30 *	-.06	.10	.17
Life expectancy	-.16	-.39 ***	.24 **	.00	-.26 **	.03	.19	.11	.34 **	.01	.09	.19

Note. Standardized effects are given.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 4

Migration Patterns, Personality, and Well-being of Respondents Who Grew Up in Old Coal Regions (N = 111 Regions in England and Wales)

	Respondents that stayed in old coal regions (Respondents current residence is still in an old coal region)	**Respondents that left old coal regions** (Respondents current residence is *not* in an old coal region)	Test of group differences	Effect sizes
Big Five personality traits				
Extraversion	3.24[a]	3.25[b]	*T* (37551) = .95	*d* = .01
Agreeableness	3.74[a]	3.75[b]	*T* (38014) = .55	*d* = .00
Conscientiousness	3.63[a]	3.7[b]	*T* (38060) = 13.04***	*d* = .09
Neuroticism	2.99[a]	2.92[b]	*T* (156560) = -11.37***	*d* = -.08
Openness	3.65[a]	3.73[b]	*T* (37349) = 19.14***	*d* = .13
Big Five sub-facets				
assertiveness	3.09[a]	3.09[b]	*T* (37484) = .44	*d* = .00
activity	3.46[a]	3.5[b]	*T* (37961) = 5.77*	*d* = .04
altruism	3.90[a]	3.88[b]	*T* (156560) = – 4.97***	*d* = -.03
compliance	3.50[a]	3.54[b]	*T* (37951) = 5.78***	*d* = .04
order	3.23[a]	3.31[b]	*T* (156560) = 13.42***	*d* = .07
self-discipline	3.62[a]	3.68[b]	*T* (38178) = 13.58***	*d* = .09
anxiety	2.98[a]	2.90[b]	*T* (156560) = -12.73***	*d* = -.09
depression	2.89[a]	2.81[b]	*T* (37405) = -10.33***	*d* = -.07
aesthetics	3.45[a]	3.58[b]	*T* (37192) = 20.07***	*d* = .14
ideas	3.68[a]	3.76[b]	*T* (37288) = 16.89***	*d* = .12
Well-being				
Life satisfaction[a]	4.75[c]	4.89[d]	*T* (36136) = 14.74***	*d* = .10

Note. Only residents in England and Wales who grew up in an old coal regions were considered. Group sizes: [a]*n* = 130240; [b]*n* = 26322; [c]*n* = 121464; [d]*n* = 24786
*p < .05. ***p < .001.

Table 5

Correlations between the Variables Used for the U.S. Analysis (N = 50 U.S. States)

	1	2	3	4	5	6	7	8
1 Distance to nearest coalfield	-							
2 Employment share in large-scale coal-based industries in 1900	-0.11	-						
3 Population density in 1900	-0.03	0.71***	-					
4 Agreeableness	0.07	-0.47***	-0.17	-				
5 Conscientiousness	-0.13	-0.46**	-0.35*	0.82***	-			
6 Extraversion	-0.13	-0.17	0.05	0.62***	0.41**	-		
7 Openness	0.07	0.15	0.15	-0.41**	-0.20	-0.51***	-	
8 Neuroticism	-0.16	0.48***	0.48***	-0.31*	-0.46***	-0.14	-0.14	-
9 Gallup Well-Being Index	0.38**	-0.08	-0.21	-0.21	-0.20	-0.13	0.18	-0.62***

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 6

Instrumental Variable Analysis Using Distance to Nearest Coalfield as Instrument for Large-Scale Coal-Based Industries in the U.S. (N = 50 U.S. States)

	DV: Employment share in large-scale coal-based industries in 1900	DV: Agreeableness	DV: Conscientiousness	DV: Extraversion	DV: Openness	DV: Neuroticism	DV: Gallup Well-Being Index
Distance to nearest coalfield	-0.00 (.00) **	–	–	–	–	–	–
Employment share in large-scale coal-based industries in 1900	–	-.594 (.33)	1.59 (.65)	0.97 (.72)	-0.93 (0.87)	1.38 (.48) **	-105.01 (33.38) **
Population density in 1900	.00 (.00) ***	.00 (.00)	-.00 (.00)	-.00 (.00)	.00 (.00)	-.00 (.00)	.04 (.02)
Constant	0.02 (0.01) ***	3.79 (.01) ***	3.57 (.01) ***	3.29 (.01) ***	3.66 (.02) ***	2.86 (.01) ***	64.03 (0.44) ***
N	50	50	50	50	50	50	50
First-Stage F-Statistics	11.22	–	–	–	–	–	–

Note. Non-standardized coefficients are given. Robust standard errors in parentheses. First stage = Prediction of employment share in large-scale coal-based industries in 1900 by the instrumental variable. Second stage = Prediction of the outcome variables using the predicted values from the first stage instead of employment share in large-scale coal-based industries in 1900.
*p < .05; **p < .01; *** p < .001

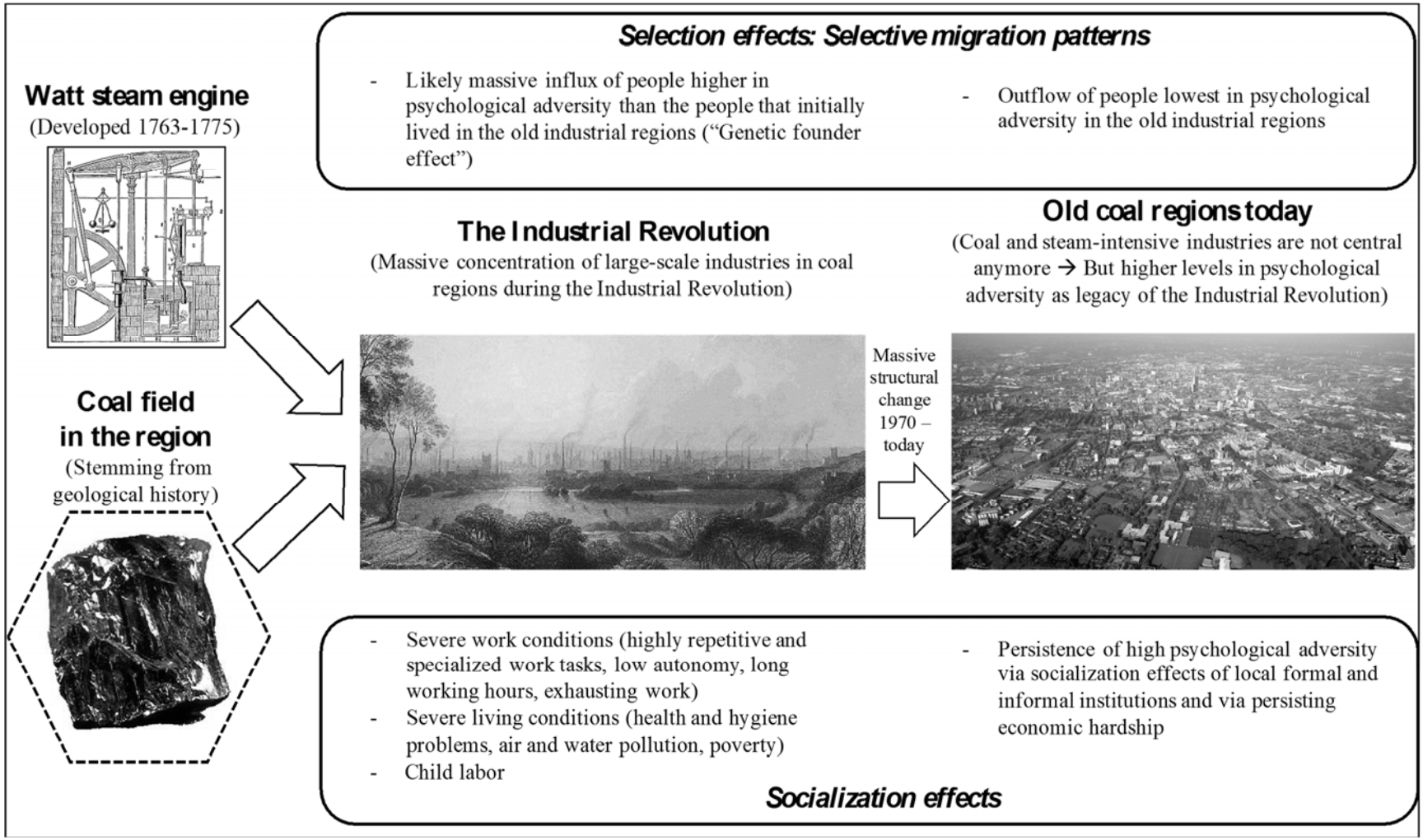

Figure 1: Mechanisms through which natural coal resources have left a sustainable psychological imprint in the old industrial regions: Temporally unfolding processes of a) selective migration patterns and b) socialization effects.

Note. Picture in the middle: "Cottonopolis" Manchester during the Industrial Revolution. Picture in the right side: Aerial view of Manchester city center in 2008 without steam-powered industry.

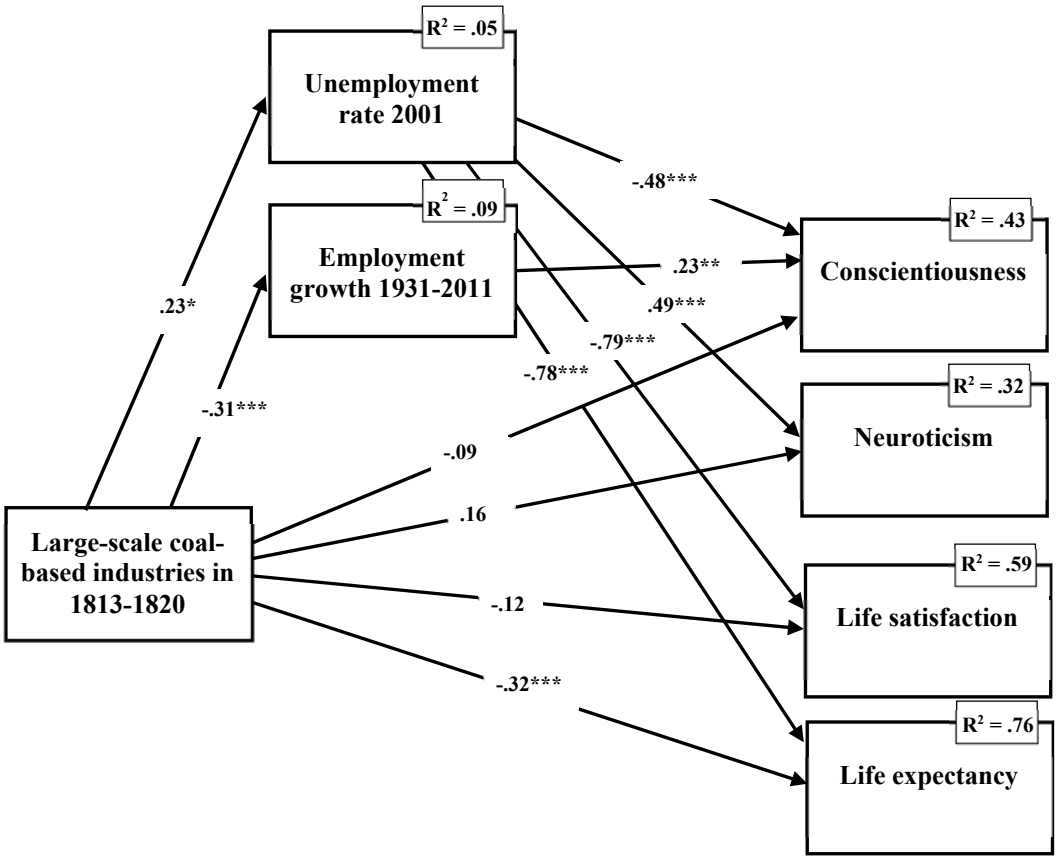

Figure 2: Mediation models including regionlevel Big Five traits for the prediction of regional differences in well-being and personality traits related to psychological adversity (*N* = 111 regions in England and Wales).

Note. Standardized regression effects are given. R^2 = Explained variance. For the sake of clarity, non-significant effects of Employment growth 1931-2011 on the outcome variables are not shown. Bootstrap mediation testing (5,000 bootstrap resamples; 95% bias-corrected confidence interval) estimated a significant indirect effect of large-scale coal-based industries via unemployment rate 2001 on Conscientiousness of ß = -.11 (95%CI = -.19 and -.05; $p < .05$), on Neuroticism of ß = .11 (95%CI = .04 and .20; $p < .05$), on life satisfaction of ß = -.18 (95%CI = -.28 and -.08; $p < .05$), and on life expectancy of ß = -.18 (95%CI = -.27 and -.08; $p < .05$). The respective significant indirect effect via employment growth 1931-2011 on Conscientiousness was ß = -.07 (95%CI = -.13 and -.03; $p < .05$).
*p < .05. **p < .01. ***p < .001.

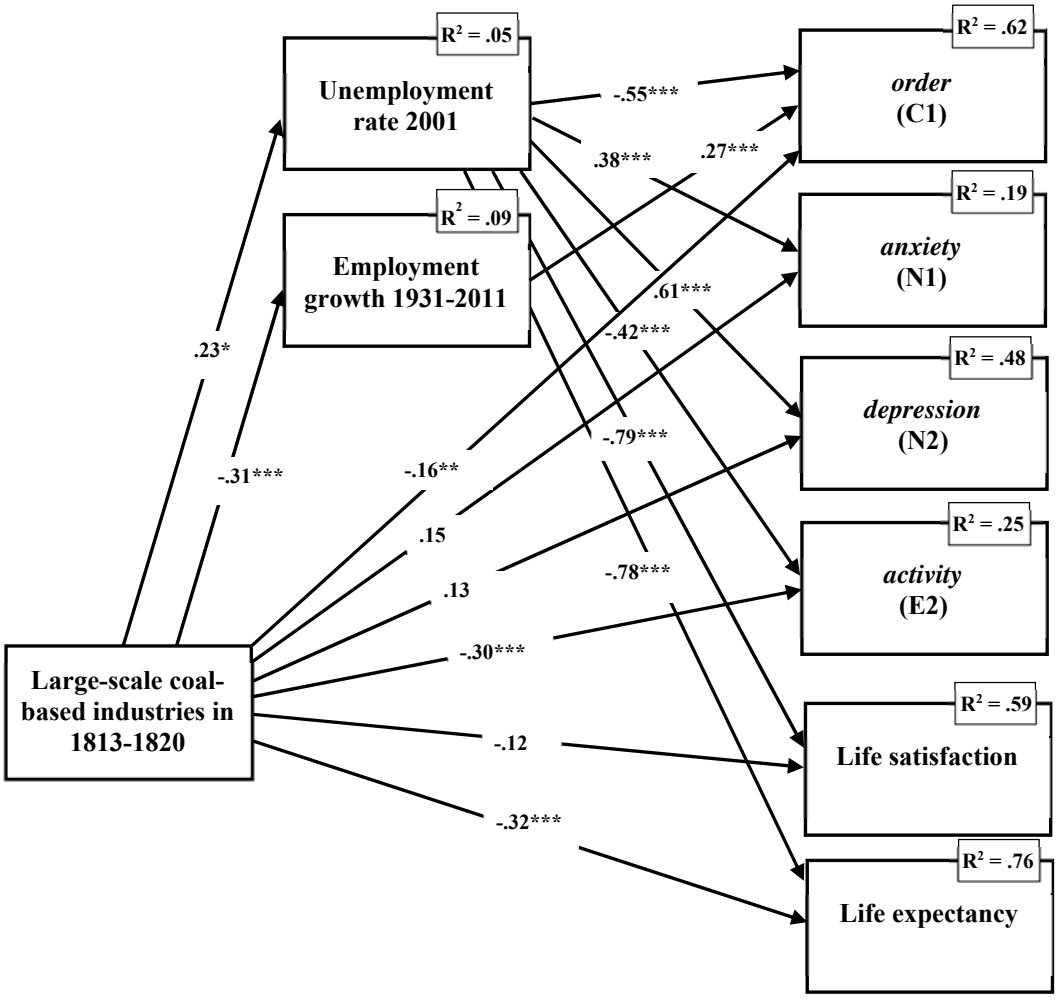

Figure 3: Mediation models including region-level Big Five sub-facets for the prediction of regional differences in well-being and personality traits related to psychological adversity (*N* = 111 regions in England and Wales).

Note. Standardized regression effects are given. R^2 = Explained variance. For the sake of clarity, non-significant effects of Employment growth 1931-2011 on the outcome variables are not shown. Bootstrap mediation testing (5,000 bootstrap resamples; 95% bias-corrected confidence interval) estimated a significant indirect effect of large-scale coal-based industries via unemployment rate 2001 on *order* (C1) of ß = -.12 (95%CI = -.20 and -.06; $p < .05$), on *anxiety* (N1) of ß = .08 (95%CI = .03 and .18; $p < .05$), on *depression* (N2) of ß = .14 (95%CI = .06 and .23; $p < .05$), on *activity* (E2) of ß = -.09 (95%CI = -.17 and -.04; $p < .05$), on life satisfaction of ß = -.18 (95%CI = -.28 and -.08; $p < .05$), and on life expectancy of ß = -.18 (95%CI = -.27 and -.08; $p < .05$). The respective significant indirect effect via employment growth 1931-2011 on *order* (C1) was ß = -.08 (95%CI = -.14 and -.03; $p < .05$).

*p < .05. **p < .01. ***p < .001.

Supplemental Material

Table S1
Industry Structure in 1813-1820 with Industry Characteristics from 1907

Industry	Average Employment share in English and Welsh regions 1813-1820	Steam-use 1907	Average plant-size 1907
Coal mining	1.6	n.a.	n.a.
Food, drink & tobacco	3.2	0.94	15.0
Chemicals	0.1	2.44	35.9
Metal manufacturers	0.8	7.10	67.6
Mechanical engineering	0.5	2.5	50.3
Instrument engineering	0.3	2.5	23.0
Electrical engineering	0.0	2.5	64.8
Shipbuilding	0.8	1.96	164.4
Vehicles	0.8	1.51	62.4
Metal goods	3.7	1.57	32.6
Textiles	7.7	5.74	155.3
Leather	1.1	0.69	28.9
Clothing & Footwear	7.0	0.45	72.0
Bricks & pottery	0.7	8.02	39.7
Timber & furniture	2.1	2.54	22.8
Paper & publishing	0.6	2.99	21.9

Note. Industries in italics are summarized as main variable: Large-scale coal-based industries. Steam use = steam horsepower per 1000 Pound of gross output. Average plant size = average Nr. of employees per plant. Data on steam-use and average plant size are taken from Crafts and Mulatu (2006, p. 591), data on average employment shares are own computations based on 1813-1820 “Census of male adult employment”.

Table S2

Correlations Between the Variables Used in This Study (N = 111 Regions in England and Wales)

Nr.	1	2	3	4	5	6	7	8
1 Distance to nearest coalfield	–							
2 Employment share in large-scale coal-based industries in 1813-1820	-.77***	–						
3 Employment share in agriculture in 1813-1820	-.13	-.09	–					
4 Employment share in services in 1813-1820	.33***	-.21*	-.35***	–				
5 Number of watermills, around 1800	-.37***	.17	.35***	-.42***	–			
6 Erected steam engines up to 1733	-.58***	.48***	.18	-.28**	.66***	–		
7 Population density in 1811	.09	.10	-.71***	.44***	-.28**	-.04	–	
8 Local church income streams in 1261	.55***	-.44***	-.22*	-.02	-.02	-.30**	-.06	–
9 University before 1500	.10	-.10	-.01	-.04	.11	-.06	-.05	.20*
10 Port around 1290	.23*	-.11	-.06	.29**	.10	-.03	.21*	.26**
11 Ruggedness	-.35***	.23*	.32**	-.38***	.52***	.32**	-.24**	-.26**
12 Depth to rock	.21*	-.15	-.29**	.04	-.06	-.04	.16	.39***
13 Limitation to agricultural use	-.03	-.09	.08	.10	-.09	-.10	-.02	-.05
14 Temperature July °C, 1960-1990	.29**	-.24**	-.28**	.33***	-.31**	-.19*	.30**	.25**
15 Unemployment rate 2001	-.15	.29**	-.02	.25***	-.37***	-.05	.21*	-.40***
16 Historical school attendance	.37***	-.32***	-.13	.34***	-.20*	-.13	.15	.41***
17 Total life expectancy	.29**	-.47***	.08	-.05	.41***	-.02	-.22*	.39***
18 Extraversion, Now Residence	.21*	-.21*	-.18	.22*	-.11	-.03	.19*	.20*
19 Agreeableness, Now Residence	-.30**	.12	.31**	-.20*	.31**	.28**	-.32**	-.24*
20 Consciousness, Now Residence	.13	-.32**	.24**	-.25**	.36***	.10	-.39***	.29**
21 Neuroticism, Now Residence	-.17	.31**	.05	.04	-.19*	-.05	.09	-.25**
22 Openness, Now Residence	-.02	-.03	-.10	.28**	.09	.10	.33***	-.07
23 Employment growth 1931-2011	.32***	.37***	-.03	-.21	-.03	-.22*	-.27**	.40***
24 Life satisfaction	-.02	-.20*	.19*	-.19*	.51***	.22*	-.29**	.27**
25 *assertiveness*	.18	-.13	-.22*	.19*	-.16	-.04	.15	.17
26 *activity*	.24*	-.37***	.04	.09	.14	.01	.05	.29**
27 *altruism*	-.21*	.11	.22*	-.18	.18	.22*	-.24*	-.19*
28 *compliance*	-.12	-.08	.22*	-.05	.31**	.12	-.21*	-.13
29 *order*	.26**	-.43***.	.04	-.18	.26**	-.02	-.22*	.46***
30 *self-discipline*	.02	-.22*	.33***	-.30**	.42***	.17	-.45***	.18
31 *anxiety*	-.15	.25**	.09	.00	-.12	.00	.00	-.17
32 *depression*	-.14	.33***	-.04	.11	-.32**	-.12	.22*	-.31**
33 *aesthetics*	-.01	-.05	-.14	.27**	.11	.10	.35***	.01
34 *ideas*	-.03	.00	-.09	.26**	.11	.12	.29**	-.08

Nr.	9	10	11	12	13	14	15	16	17	18	19	20	21
9	–												
10	-.05	–											
11	.02	-.10	–										
12	.02	.17	-.29**	–									
13	-.02	-.06	-.09	-.21*	–								
14	.09	.16	-.73***	.21*	.04	–							
15	-.17	-.01	-.10	-.15	.04	-.10	–						
16	.06	.18	-.46***	.42***	-.04	.30*	-.18	–					
17	.17	.12	.07	.13	.04	.08	-.82***	.23*	–				
18	-.04	.00	-.22*	.11	.19	.22*	-.21*	.37***	.25***	–			
19	-.05	-.04	.16	-.26**	.00	-.15	-.10	-.22*	.07	-.02	–		
20	.06	.03	-.05	.18	-.13	.06	-.61***	.12	.62***	.11	.41***	–	
21	-.02	-.05	.05	-.14	.00	-.14	.54***	-.26**	-.59***	-.55***	-.31**	-.55***	–
22	.17	.16	.08	-.14	.30**	.04	.01	.11	.12	.40***	-.11	-.32**	-.14
23	.09	-.11	-.17	.14	-.05	.13	-.52***	-.02	.44***	.04	.01	.50***	-.34***
24	.18	.01	.14	.05	.04	-.01	-.76***	.20*	.80***	.26**	.32**	.68***	-.62***
25	-.09	-.06	-.27**	.12	.17	.20*	-.17	.32***	.15	.94***	-.02	.08	-.45***
26	.09	.10	-.03	.04	.12	.16	-.41***	.32***	.52***	.74***	.08	.35***	-.63***
27	-.15	-.03	.09	-.22*	-.07	-.10	.01	-.17	-.11	-.11	.85***	.36***	-.09
28	.10	.07	.18	-.26**	.09	-.05	-.25**	-.18	.33***	.10	.73***	.29**	-.47***
29	.07	.06	-.16	.29**	-.11	.23*	-.72***	.23*	.70***	.18	.21*	.90***	-.56***
30	.05	.02	.03	.12	-.11	-.03	-.54***	.04	.55***	.05	.47***	.97***	-.50***
31	-.03	-.06	.05	-.05	-.08	-.16	.41***	-.17	-.45***	-.55***	-.23*	-.38***	.93***
32	-.05	-.04	-.01	-.20*	.07	-.06	.67***	-.30***	-.72***	-.45***	-.35***	-.69***	.89***
33	.18	.20*	.01	-.07	.29**	.08	-.05	.19*	.17	.41***	-.11	-.26**	-.13
34	.18	.15	.13	-.13	.28**	.04	.00	.07	.12	.37***	-.14	-.33***	-.16

Nr.	22	23	24	25	26	27	28	29	30	31	32	33	34
22	–												
23	-.32***	–											
24	.07	.33***	–										
25	.25**	.04	.17	–									
26	.50***	.16	.52***	.50***	–								
27	-.27**	.04	.13	-.07	-.09	–							
28	.23*	-.03	.40***	.03	.32**	.34***	–						
29	-.30**	.60***	.67***	.15	.38***	.21*	.15	–					
30	-.31**	.41***	.68***	.03	.30**	.40***	.34***	.79***	–				
31	-.26**	-.24*	-.47***	-.45***	-.59***	-.02	-.45***	-.40***	-.34***	–			
32	-.02	-.42***	-.75***	-.36***	-.60***	-.18	-.43***	-.69***	-.65***	.68***	–		
33	.94***	-.26**	.16	.26**	.49***	-.22*	.17	-.19	-.27**	-.22*	-.07	–	
34	.96***	-30**	.06	.22*	.46***	-.32**	.22*	-.33***	-.32**	-.29**	-.03	.83***	–

*$p < .05$. **$p < .01$. ***$p < .001$.

Table S3

Hierarchical Regression Analysis for the Prediction of Regional Differences in Conscientiousness

	Step 1			*Step 2*		
	B	SE B	β	B	SE B	β
Historical industry structure						
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.35 ***	.00	.00	-.26 **
Employment share in services in 1813-1820	.00	.00	-.36 ***	.00	.00	-.19
Employment share in agriculture in 1813-1820	.00	.00	-.09	.00	.00	-.18
Control variables						
Number of watermills, around 1800				.00	.00	.25 **
Erected steam engines up to 1733				.00	.00	.02
Population density in 1811				.00	.00	-.39 ***
Local church income streams in 1291				.00	.02	.01
School attendance rate in 1851				.00	.00	.01
Port around 1290				.01	.01	.08
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	-.12
Depth to rock				.01	.01	.10
Limitation to agricultural use				-.01	.01	-.10
Temperature July °C, 1960-1990				.00	.01	.05
R^2 (adjusted)		.16			.29	
N		111			111	

Note. *p < .05. **p < .01. ***p < .001.

Table S4

Hierarchical Regression Analysis for the Prediction of Regional Differences in Neuroticism

	Step 1			*Step 2*		
	B	SE B	β	B	SE B	β
Historical industry structure						
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	.37 ***	.00	.00	.33 **
Employment share in services in 1813-1820	.00	.00	.21 *	.00	.00	.22
Employment share in agriculture in 1813-1820	.00	.00	.31 **	.00	.00	.48 ***
Control variables						
Number of watermills, around 1800				.00	.00	-.11
Erected steam engines up to 1733				.00	.00	-.01
Population density in 1811				.00	.00	.24 *
Local church income streams in 1291				.02	.01	.16
School attendance rate in 1851				.00	.00	-.31 **
Port around 1290				-.01	.01	-.09
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	-.24
Depth to rock				.00	.00	.01
Limitation to agricultural use				.00	.01	-.05
Temperature July °C, 1960-1990				-.01	.01	-.20
R^2 (adjusted)		.15			.20	
N		111			111	

Note. *p < .05. **p < .01. ***p < .001.

Table S5

Hierarchical Regression Analysis for the Prediction of Regional Differences in Extraversion

	Step 1				*Step 2*			
	B	SE B	β		B	SE B	β	
Historical industry structure								
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.15		.00	.00	-.04	
Employment share in services in 1813-1820	.00	.00	.12		.00	.00	.01	
Employment share in agriculture in 1813-1820	.00	.00	-.21	*	.00	.00	-.14	
Control variables								
Number of watermills, around 1800					.00	.00	-.03	
Erected steam engines up to 1733					.00	.00	.00	
Population density in 1811					.00	.00	.09	
Local church income streams in 1291					.00	.01	.05	
School attendance rate in 1851					.00	.00	.37	**
Port around 1290					-.01	.01	-.10	
Ruggedness (Difference between the maximum and minimum elevation)					.00	.00	.14	
Depth to rock					.00	.00	-.05	
Limitation to agricultural use					.02	.01	.21	*
Temperature July °C, 1960-1990					.01	.01	.13	
R^2 (adjusted)		.07				.13		
N		111				111		

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Table S6

Hierarchical Regression Analysis for the Prediction of Regional Differences in Agreeableness

	Step 1			*Step 2*			
	B	SE B	β	B	SE B	β	
Historical industry structure							
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	.11	.00	.00	.01	
Employment share in services in 1813-1820	.00	.00	-.14	.00	.00	-.11	
Employment share in agriculture in 1813-1820	.00	.00	.16	.00	.00	-.17	
Control variables							
Number of watermills, around 1800				.00	.00	.18	
Erected steam engines up to 1733				.00	.00	.02	
Population density in 1811				.00	.00	-.36	**
Local church income streams in 1291				-.02	.01	-.30	*
School attendance rate in 1851				.00	.00	-.04	
Port around 1290				.01	.01	.16	
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	-.12	
Depth to rock				.00	.00	-.17	
Limitation to agricultural use				.00	.01	-.02	
Temperature July °C, 1960-1990				.00	.00	-.01	
R^2 (adjusted)		.05			.15		
N		111			111		

Note. *$p < .05$. **$p < .01$. ***$p < .001$.

Table S7

Hierarchical Regression Analysis for the Prediction of Regional Differences in Openness

	Step 1				*Step 2*			
	B	SE B	β		B	SE B	β	
Historical industry structure								
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.02		.00	.00	-.07	
Employment share in services in 1813-1820	.00	.00	.31	**	.00	.00	.16	
Employment share in agriculture in 1813-1820	.00	.00	.06		.00	.00	.04	
Control variables								
Number of watermills, around 1800					.00	.00	.12	
Erected steam engines up to 1733					.00	.00	.04	
Population density in 1811					.00	.00	.34	**
Local church income streams in 1291					.00	.01	-.02	
School attendance rate in 1851					.00	.00	.17	
Port around 1290					.01	.01	.06	
Ruggedness (Difference between the maximum and minimum elevation)					.00	.00	.31	*
Depth to rock					-.01	.00	-.13	
Limitation to agricultural use					.03	.01	.31	***
Temperature July °C, 1960-1990					.01	.01	.10	
R^2 (adjusted)		.06				.26		
N		111				111		

Note. *p < .05. **p < .01. ***p < .001.

Table S8

Hierarchical Regression Analysis for the Prediction of Regional Differences in Order (C1)

	Step 1			*Step 2*		
	B	SE B	β	B	SE B	β
Historical industry structure						
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.49 ***	.00	.00	-.35 ***
Employment share in services in 1813-1820	-.01	.00	-.40 ***	.00	.00	-.30 **
Employment share in agriculture in 1813-1820	.00	.00	-.31 ***	.00	.00	-.29 **
Control variables						
Number of watermills, around 1800				.00	.00	.19 *
Erected steam engines up to 1733				.00	.00	-.02
Population density in 1811				.00	.00	-.24 *
Local church income streams in 1291				.02	.02	.08
School attendance rate in 1851				.00	.00	.07
Port around 1290				.01	.02	.07
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	-.03
Depth to rock				.01	.01	.11
Limitation to agricultural use				-.01	.01	-.06
Temperature July °C, 1960-1990				.01	.01	.17
R^2 (adjusted)		.28			.38	
N		111			111	

Note. *p < .05. **p < .01. ***p < .001.

Table S9

Hierarchical Regression Analysis for the Prediction of Regional Differences in Self-Discipline (C2)

	Step 1			*Step 2*		
	B	SE B	β	B	SE B	β
Historical industry structure						
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.25 **	.00	.00	-.19
Employment share in services in 1813-1820	.00	.00	-.35 ***	.00	.00	-.17
Employment share in agriculture in 1813-1820	.00	.00	.01	.00	.00	-.15
Control variables						
Number of watermills, around 1800				.00	.00	.26 **
Erected steam engines up to 1733				.00	.00	.03
Population density in 1811				.00	.00	-.44 ***
Local church income streams in 1291				-.01	.02	-.06
School attendance rate in 1851				.00	.00	-.01
Port around 1290				.02	.01	.11
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	-.15 *
Depth to rock				.01	.01	.11
Limitation to agricultural use				-.01	.01	-.08
Temperature July °C, 1960-1990				.00	.01	.00
R^2 (adjusted)		.13			.28	
N		111			111	

Note. *p < .05. **p < .01. ***p < .001.

Table S10

Hierarchical Regression Analysis for the Prediction of Regional Differences in Anxiety (N1)

	Step 1			*Step 2*		
	B	SE B	β	B	SE B	β
Historical industry structure						
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	.31 **	.00	.00	.31 **
Employment share in services in 1813-1820	.00	.00	.15	.00	.00	.24
Employment share in agriculture in 1813-1820	.00	.00	.32 **	.00	.00	.49 ***
Control variables						
Number of watermills, around 1800				.00	.00	-.05
Erected steam engines up to 1733				.00	.00	.01
Population density in 1811				.00	.00	.15
Local church income streams in 1291				.02	.01	.19
School attendance rate in 1851				.00	.00	-.26 *
Port around 1290				-.01	.01	-.12
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	-.25
Depth to rock				.00	.00	.08
Limitation to agricultural use				-.01	.01	-.11
Temperature July °C, 1960-1990				-.01	.01	-.22
R^2 (adjusted)		.11			.12	
N		111			111	

Note. *p < .05. **p < .01. ***p < .001.

Table S11

Hierarchical Regression Analysis for the Prediction of Regional Differences in Depression (N2)

	Step 1			*Step 2*		
	B	SE B	β	B	SE B	β
Historical industry structure						
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	.38 ***	.00	.00	.31 **
Employment share in services in 1813-1820	.00	.00	.28 **	.00	.00	.19
Employment share in agriculture in 1813-1820	.00	.00	.27 **	.00	.00	.45 ***
Control variables						
Number of watermills, around 1800				.00	.00	-.22 *
Erected steam engines up to 1733				.00	.00	-.05
Population density in 1811				.00	.00	.34 **
Local church income streams in 1291				.02	.02	.10
School attendance rate in 1851				.00	.00	-.33 **
Port around 1290				-.01	.02	-.07
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	-.21
Depth to rock				.00	.01	-.05
Limitation to agricultural use				.00	.01	.00
Temperature July °C, 1960-1990				-.01	.01	-.13
R^2 (adjusted)		.15			.32	
N		111			111	

Note. *p < .05. **p < .01. ***p < .001.

Table S12

Hierarchical Regression Analysis for the Prediction of Regional Differences in Assertiveness (E1)

	Step 1				*Step 2*			
	B	SE B	β		B	SE B	β	
Historical industry structure								
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.05		.00	.00	.07	
Employment share in services in 1813-1820	.00	.00	.09		.00	.00	.02	
Employment share in agriculture in 1813-1820	.00	.00	-.25	*	.00	.00	-.20	
Control variables								
Number of watermills, around 1800					.00	.00	-.04	
Erected steam engines up to 1733					.00	.00	.01	
Population density in 1811					.00	.00	-.01	
Local church income streams in 1291					.00	.01	.04	
School attendance rate in 1851					.00	.00	.31	*
Port around 1290					-.01	.01	-.12	
Ruggedness (Difference between the maximum and minimum elevation)					.00	.00	-.02	
Depth to rock					.00	.00	-.04	
Limitation to agricultural use					.01	.01	.18	
Temperature July °C, 1960-1990					.00	.01	.05	
R^2 (adjusted)		.06				.11		
N		111				111		

Note. *p < .05. **p < .01. ***p < .001.

Table S13

Hierarchical Regression Analysis for the Prediction of Regional Differences in Activity (E2)

	Step 1				*Step 2*			
	B	SE B	β		B	SE B	β	
Historical industry structure								
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.36	***	.00	.00	-.24	*
Employment share in services in 1813-1820	.00	.00	-.01		.00	.00	-.04	
Employment share in agriculture in 1813-1820	.00	.00	-.07		.00	.00	-.01	
Control variables								
Number of watermills, around 1800					.00	.00	.08	
Erected steam engines up to 1733					.00	.00	-.01	
Population density in 1811					.00	.00	.11	
Local church income streams in 1291					.02	.01	.18	
School attendance rate in 1851					.00	.00	.31	*
Port around 1290					.00	.01	-.01	
Ruggedness (Difference between the maximum and minimum elevation)					.00	.00	.33	*
Depth to rock					-.01	.01	-.11	
Limitation to agricultural use					.01	.01	.13	
Temperature July °C, 1960-1990					.01	.01	.21	
R^2 (adjusted)		.10				.18		
N		111				111		

Note. *p < .05. **p < .01. ***p < .001.

Table S14

Hierarchical Regression Analysis for the Prediction of Regional Differences in Altruism (A1)

	Step 1			*Step 2*			
	B	SE B	β	B	SE B	β	
Historical industry structure							
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	.16	.00	.00	.10	
Employment share in services in 1813-1820	.00	.00	-.10	.00	.00	-.09	
Employment share in agriculture in 1813-1820	.00	.00	.15	.00	.00	-.07	
Control variables							
Number of watermills, around 1800				.00	.00	.11	
Erected steam engines up to 1733				.00	.00	.04	
Population density in 1811				.00	.00	-.26	*
Local church income streams in 1291				-.01	.01	-.19	
School attendance rate in 1851				.00	.00	-.03	
Port around 1290				.01	.01	.12	
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	-.16	
Depth to rock				.00	.00	-.18	
Limitation to agricultural use				-.01	.01	-.10	
Temperature July °C, 1960-1990				.00	.00	.00	
R^2 (adjusted)		.04			.06		
N		111			111		

Note. *p < .05. **p < .01. ***p < .001.

Table S15

Hierarchical Regression Analysis for the Prediction of Regional Differences in Compliance (A2)

	Step 1			*Step 2*			
	B	SE B	β	B	SE B	β	
Historical industry structure							
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.08	.00	.00	-.18	
Employment share in services in 1813-1820	.00	.00	-.06	.00	.00	-.04	
Employment share in agriculture in 1813-1820	.00	.00	.07	.00	.00	-.26	
Control variables							
Number of watermills, around 1800				.00	.00	.19	
Erected steam engines up to 1733				.00	.00	-.04	
Population density in 1811				.00	.00	-.28	*
Local church income streams in 1291				-.02	.01	-.25	
School attendance rate in 1851				.00	.00	-.04	
Port around 1290				.02	.01	.21	
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	.13	
Depth to rock				-.01	.00	-.19	
Limitation to agricultural use				.01	.01	.07	
Temperature July °C, 1960-1990				.00	.00	.13	
R^2 (adjusted)		-.01			.11		
N		111			111		

Note. *p < .05. **p < .01. ***p < .001.

Table S16

Hierarchical Regression Analysis for the Prediction of Regional Differences in Aesthetics (O1)

	Step 1				*Step 2*			
	B	SE B	β		B	SE B	β	
Historical industry structure								
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.05		.00	.00	-.08	
Employment share in services in 1813-1820	.00	.00	.25	*	.00	.00	.07	
Employment share in agriculture in 1813-1820	.00	.00	-.01		.00	.00	.00	
Control variables								
Number of watermills, around 1800					.00	.00	.14	
Erected steam engines up to 1733					.00	.00	.05	
Population density in 1811					.00	.00	.37	**
Local church income streams in 1291					.00	.02	.01	
School attendance rate in 1851					.00	.00	.23	
Port around 1290					.02	.02	.10	
Ruggedness (Difference between the maximum and minimum elevation)					.00	.00	.23	
Depth to rock					-.01	.01	-.13	
Limitation to agricultural use					.05	.01	.31	***
Temperature July °C, 1960-1990					.00	.01	.06	
R^2 (adjusted)		.05				.25		
N		111				111		

Note. *p < .05. **p < .01. ***p < .001.

Table S17

Hierarchical Regression Analysis for the Prediction of Regional Differences in Ideas (O2)

	Step 1				*Step 2*			
	B	SE B	β		B	SE B	β	
Historical industry structure								
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.01		.00	.00	-.05	
Employment share in services in 1813-1820	.00	.00	.30	**	.00	.00	.21	
Employment share in agriculture in 1813-1820	.00	.00	.07		.00	.00	.03	
Control variables								
Number of watermills, around 1800					.00	.00	.11	
Erected steam engines up to 1733					.00	.00	.05	
Population density in 1811					.00	.00	.28	*
Local church income streams in 1291					.00	.01	.00	
School attendance rate in 1851					.00	.00	.13	*
Port around 1290					.00	.01	.04	
Ruggedness (Difference between the maximum and minimum elevation)					.00	.00	.43	**
Depth to rock					.00	.00	-.09	
Limitation to agricultural use					.03	.01	.29	***
Temperature July °C, 1960-1990					.01	.01	.19	
R^2 (adjusted)		.06				.24		
N		111				111		

Note. *p < .05. **p < .01. ***p < .001.

Table S18

Hierarchical Regression Analysis for the Prediction of Regional Differences in Life Satisfaction

	Step 1			*Step 2*		
	B	SE B	β	B	SE B	β
Historical industry structure						
Employment share in large-scale coal-based industries in 1813-1820	.00	.00	-.35 ***	.00	.00	-.29 **
Employment share in services in 1813-1820	-.01	.00	-.35 ***	.00	.00	-.26 *
Employment share in agriculture in 1813-1820	.00	.00	-.15	-.01	.00	-.36 **
Control variables						
Number of watermills, around 1800				.00	.00	.30 ***
Erected steam engines up to 1733				.00	.00	-.01
Population density in 1811				.00	.00	-.29 **
Local church income streams in 1291				-.01	.03	-.05
School attendance rate in 1851				.00	.00	.33 **
Port around 1290				.02	.03	.08
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	.30 *
Depth to rock				-.01	.01	-.06
Limitation to agricultural use				.02	.02	.10
Temperature July °C, 1960-1990				.02	.01	.17
R^2 (adjusted)		.15			.35	
N		111			111	

Note. *p < .05. **p < .01. ***p < .001.

Table S19

Hierarchical Regression Analysis for the Prediction of Regional Differences in Life Expectancy

	Step 1			*Step 2*		
	B	SE B	β	B	SE B	β
Historical industry structure						
Employment share in large-scale coal-based industries in 1813-1820	-.06	.01	-.57 ***	-.05	.01	-.50 ***
Employment share in services in 1813-1820	-.06	.02	-.28 **	-.03	.02	-.16
Employment share in agriculture in 1813-1820	-.04	.01	-.25 **	-.07	.02	-.39 ***
Control variables						
Number of watermills, around 1800				.00	.00	.24 **
Erected steam engines up to 1733				.00	.05	.00
Population density in 1811				.00	.00	-.26 **
Local church income streams in 1291				.09	.33	.03
School attendance rate in 1851				.02	.01	.19
Port around 1290				.43	.32	.11
Ruggedness (Difference between the maximum and minimum elevation)				.00	.00	.34 **
Depth to rock				.01	.11	.01
Limitation to agricultural use				.25	.22	.09
Temperature July °C, 1960-1990				.26	.15	.19
R^2 (adjusted)		.30			.45	
N		111			111	

Note. *p < .05. **p < .01. ***p < .001.

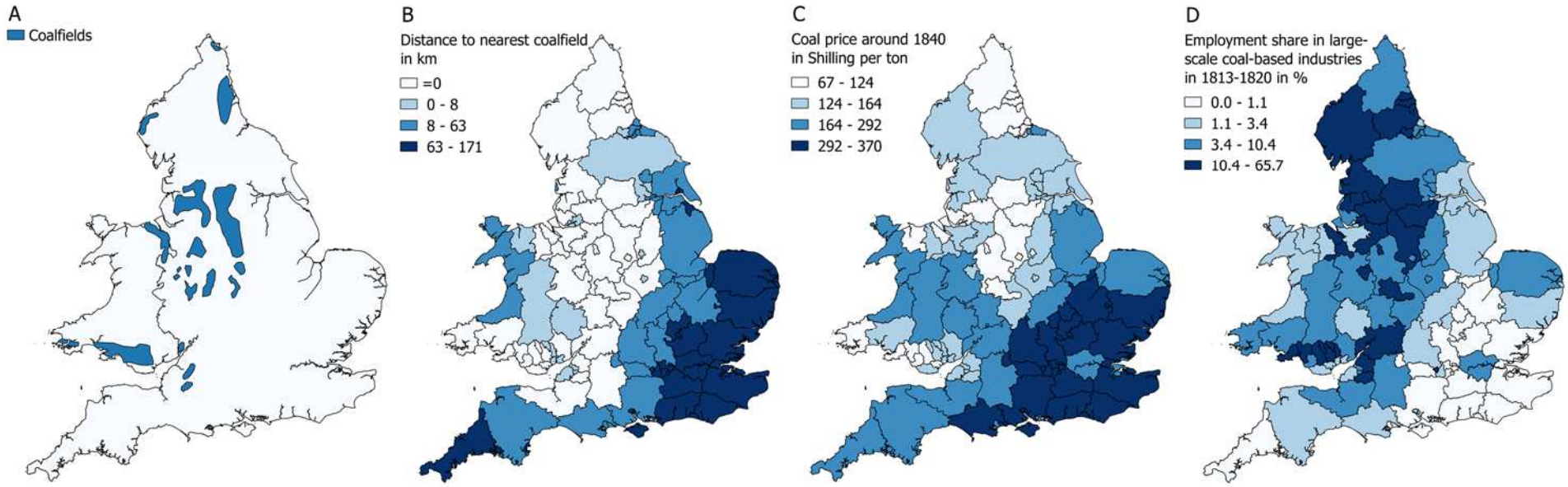

Figure S1: Coalfields and large-scale coal-based industries in England and Wales. A) Coalfields before 1700. B) Distance to the nearest coalfield before 1700 (Instrumental variable). C) Coal price around 1840. D) Employment share in large-scale coal-based industries in 1813-1820.

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