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Minnesota—too late for a Sovereign Wealth Fund?

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Abstract

Ten states have created natural-resource-based Sovereign Wealth Funds (SWF) to allow a fraction of the wealth derived from the extraction of non-renewable resources to be available for future use. Minnesota does not have a SWF, even though companies have been mining in the state for over 100 years. Herein, we present backward and forward-looking scenarios to estimate the potential magnitude of a "what-if" extraction-based fund. A 1.5% of value tax is suggested as an SWF funding mechanism. Based on historical extraction, prices, and investment returns, a large SWF could already exist. In the forward-looking section, we begin by econometrically estimating the supply and demand of US iron ore production to better understand how an increase in mining taxes would likely effect mining output (i.e., the production effect). After accounting for an estimated 4% production loss, results suggest enough minerals could still be extracted to create a permanent fund with between $930 million (US) and $1.6 billion dollars (US) in direct contributions by 2050 (depending on price). Using reasonable assumptions of a 2% inflation rate and a 5% annual investment return, the fund size could range from $3 billion to $5 billion by 2050.

Keywords Sovereign Wealth Fund (SWF) · Permanent natural resource trust fund · Intergenerational transfer · Production effect · Welfare estimates · Financial returns

JEL Classification Q320 · O130

Highlights:
- Despite mining for over 100 years, Minnesota does not have a Sovereign Wealth Fund.
- Based on extraction, backward looking analysis suggests a large SWF could exist.
- Adding a 1.5% value tax to fund a SWF would create an estimated 4% production loss.
- Reserves could generate a fund with $1 billion in direct contributions by 2050.
- With 2% inflation and a 5% investment return, a $3-$5 billion fund is possible by 2050.

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Introduction

In the USA, ten states have taxed or diverted fees to create Sovereign Wealth Funds (SWF), publicly owned investment funds, to accumulate wealth for when their non-renewable natural resources are exhausted (e.g., natural gas, oil, coal and other minerals). Alaska, New Mexico, and Wyoming are three prominent examples. These states are trying to diversify their resource-dependent economies by transforming a stock of natural gas, oil, and coal reserves into a stock of wealth that can be invested broadly for citizens today and those off into the far distant future (see e.g., Megginson and Fotak 2015; van den Bremer et al. 2016). These SWF funds are progressive and forward-looking: revenues obtained from the resources accumulate and a portion is re-invested to promote intergenerational equity. Curiously, however, the state of Minnesota, which many view as progressive, does not have an SWF, even though companies have been mining iron ore and taconite for over 100 years.

Three reasons suggest that Minnesota could have created and might still want to consider creating an SWF. First, Minnesota has the natural resources.[1] The state has a long history of mining both high-grade natural iron ore and low-grade iron ore rock. The first iron ore shipments were in the late 1800s (Minnesota Department of Natural Resources 2018). Starting in the mid-1950s, a noticeable change in production occurred; a significant shift toward more production of low-grade iron ore pellets. Iron ore pellets, a.k.a. taconite pellets, are created when low grade iron ore rock is crushed and separated, clay and water are then added to the ore to make a slurry pellet, which is then baked and capable of being shipped. In 1955, about 98% of iron ore production was from high-grade ore. This percentage fell to around 50% in 1967 and to about 5% in 1980 (Minnesota Department of Revenue 1985). The industry has been an important source of employment, especially for iron-range communities. Direct employment counts generally increased to approximately 14,500 in 1951 before generally declining to approximately 4,500 in 2014 (United States Geological Survey 2018). In total, from 1931 to 2014, Minnesota produced 3.89 billion metric tons of useable ore with a cumulative unadjusted shipped-value of $83.5 billion USD (USGS).

Second, the potential size of the intergeneration transfer of wealth can be substantial. For example, Norway's Government Pension Fund was established in 1990 and made headlines by eclipsing $1 trillion USD in total assets in September 2017 (see, e.g., Papaioannou and Rentsendorj 2015; McCarthy 2017). The purpose of the fund is "The Government Pension Fund Global is saving for future generations in Norway. One day the oil will run out, but the return on the fund will continue to benefit the Norwegian population" (Norges Bank Investment Management 2020). The same site suggests a portion of the fund value can be used in the national budget and that an estimated $28 billion USD was transferred in 2017. According to the Norwegian Ministry of Finance document "Budget 2017", the total expenditure of the fiscal budget was about $156 billion USD. A back of the envelope calculation suggests that about 18% of budget expenditures were covered by the fund (Norwegian Ministry of Finance 2017).

Third, having a recurring and potentially growing source of contributions to revenues could be advantageous for the state. The assets in most SWFs are managed using portfolio techniques and often yield significant returns. For example, the self-reported annual total returns from the Alaska Permanent Fund, with current assets of $62 billion, have averaged 9.6% (Alaska Permanent Fund Corporation 2017). Minnesota's recent annual state budget expenditures are around $20 billion (Minnesota Department of Management and Budget 2017).

In theory, the existence of an SWF for Minnesota with $20 billion in assets, that could generate a 10% return, would contribute a non-trivial 10% of the state's budgeted expenditures. Of course, many other return and distribution scenarios are possible. Yet, the basic scenario highlights the point that a permanent SWFs can generate large sums of wealth with protected principles and the significant returns can be redistributed to current and future generations. Of course, such investments incur opportunity costs and we do not seek to answer the normative question of whether such a fund should be created. Empirically, many states and countries have moved forward with such funds despite their inherent opportunity costs.

Herein, we explore three research questions to further understand: (1) What if Minnesota had created a permanent Sovereign Wealth Fund early in its production history or if it, as did several other states, had started one in the mid-1970s? (2) Would it be worthwhile to consider starting a fund in Minnesota, given the current level of estimated mineral reserves? And (3) What are the current economic issues associated with creating such a fund for Minnesota? We estimate two types of scenarios addressing a Minnesota SWF: "what-if" (backward-looking) and "what about the future" (forward-looking) scenarios. A 1.5% of value tax is used to fund the SWF. Based on historical iron ore extraction and financial investment returns, it is estimated that a fund, focused solely on principal growth, could have generated a fund balance between $2.3 and $27.1 billion (nominal USD) depending on the fund starting year and investment choices. After

[1] Minnesota has long been a major producer of iron ore in the USA. International competition, however, since the 1950s has reduced its global share (USGS 2018). Its share of US production generally rose from an average of 60% in the 1930s to 74% post-2000. Minnesota and US production shares, however, have fallen sharply compared to world production; shares decreased from 32 to 48% from 1945 to 1950 to 1.6% and 2.1% from 2010 to 2014. Despite this trend and some large annual production fluctuations, since 1980, Minnesota has produced an average of 40 million metric tons (a.k.a. tonnes) of taconite pellets per year (1980-2014).

accounting for an estimated 4% production loss, due to an increased tax rate, results suggest enough minerals could still be extracted to create a permanent fund with about $930 million (US) to $1.6 billion dollars (US) in direct contributions by 2050 (depending on price). Using reasonable assumptions of a 2% inflation rate and a 5% annual investment return, the fund size could range from $3 billion to $5 billion by 2050. Although controversial within the state, two proposed copper-nickel mines could also contribute to an extraction based SWF.

The paper contributes to the literature in the following ways. We create a framework for analyzing the foregone opportunity of creating an SWF based on several investment types, including the returns of several existing US state funds. We provide an updated supply and demand model and supply elasticity for US iron ore production. In addition, we utilize the model results to estimate the production effect from an increase in a mining tax; the authors are unaware of any papers doing so for iron ore. Also, we are able to use the production effect to increase the reliability of our forward-looking estimates. Further, we expect the results would be of interest to policy makers in states and countries that either have a history of extraction or potential new projects.

This paper starts with a literature review on SWFs. The following section provides background on state SWFs and Minnesota. Next, we analyze backward-looking scenarios to estimate the potential size of an SWF, if one had been created, based on historic extraction and investment returns. In the forward-looking section, we begin by econometrically estimating the supply and demand of US iron ore production to better understand how an increase in mining taxes would likely effect mining output (i.e., the production effect). Subsequently, reserves and future price ranges are examined to provide estimates of the 2050 value of a newly created SWF. We conclude by trying to determine if it is too late to start an SWF by considering the estimated magnitude of the SWF principal, the amount of the possible annual investment rents that could be generated, and how those rents might be utilized.

Literature review on Sovereign Wealth Funds

Social scientists continue to try to untangle the potential existence of a "resource curse," hypothesized from the correlation of slow growth in the presence of natural resource abundance (see for example: Gelb 1988; Auty 1993; Sachs and Warner 1995; James 2016). Recent literature reviews have concluded that the curse is not inevitable (Van der Ploeg 2011; Badeeb et al. 2017) and similarly that the empirical evidence for the existence of the "Dutch disease" version of the curse, crowding out of traditional export industries, is "… by no means inevitable at the national level" (Nülle and Davis 2018, p. 55). Recommendations for how to attempt to avoid a potential curse often involve a suite of policies to try to address its multifaceted nature.

One dimension typically desired is to create policies that utilize non-renewable resource wealth to promote intergenerational welfare. Al Faruque (2006, p.82) notes this as a primary goal in creating a national resource fund (a.k.a. Sovereign Wealth Fund, permanent fund): "The national resource fund is usually entrusted with managing revenues placed under its control and acts as a trustee for the benefit of citizens, including future generations." Sovacool (2016) discusses that creating a Sovereign Wealth Fund (SWF) can be one tool to promote prudence in practice and focuses on São Tomé e Príncipe as an example of a country that created an SWF and accompanied it with additional policies and laws to help ensure its purpose is met. Nülle and Davis (2018, p. 39) point out that "… concerns about intergenerational welfare can be addressed via capital market activities such as Sovereign Wealth Funds that are aimed at smoothing consumption." Recently, Bishoge and Mvile (2020) included creation of an SWF to make savings available to the next generation in their recommendations for how Tanzania might avoid the "resource curse."

Sovereign Wealth Funds are state-owned and state-controlled investment funds. SWFs invest their assets globally in various assets (financial and real) based on the interests and objectives of the state. They also have no outside beneficiaries or liabilities, beyond the citizenry (Monk 2009). SWFs have several main purposes: macroeconomic stabilization of government revenues (e.g., insulate the country/state against commodity price shocks), saving the wealth generated by non-renewable resources to share with future generations, promotion of domestic industries (e.g., encourage creation and expansion of new industries), and to manage foreign reserves (see Blackburn et al. 2008; Alhashel 2015; Ossowski and Halland 2017). Although SWFs rarely publish information about their assets, liabilities, or investment strategies, they have become key players in global finance given their substantial size, with nearly $8 trillion in assets. Kuwait started the first SWF in 1953. Today, the five largest SWFs are the Norwegian government Pension fund ($1.1 trillion); China Investment Corporation ($940 billion); Abu Dhabi Investment Authority ($580 billion); Kuwait Investment Authority ($534 billion); and Hong Kong Monetary Authority Investment Portfolio ($528 billion) (see Sovereign Wealth Fund Institute 2020). The largest SWFs in North America are found in Alberta, Alaska, Texas, New Mexico, Wyoming, and North Dakota. Of course, creation of an SWF comes with challenges and they are not without controversy; however, the literature has helped identify some problems and provided some recommendations (see, for example: Truman 2009; Schubert and Barenbaum 2010; Megginson and Gao 2020).

SWFs vary in their balance of the use of the funds between the current and future generation. For example, the Alaska Permanent Fund pays out a Permanent Fund Dividend (PDF) annually to qualifying residents (Anderson 2002). Kozminski and Baek (2017) found that while the PDF does not reduce income inequality, it does make individuals better off via the income effect. O'Brien and Olson (1990) suggest it has antirecessionary effects. Berman (2018) finds that the PDF has decreased the poverty rates of rural Alaska Indigenous people. Chung et al. (2016) find it has a statistically positive but small effect on birthweight. Watson et al. (2020) find that while substance abuse temporarily increases after payment distribution, the overall crime effects from the program are minimal.

Background

One of the most recognizable state funds is Alaska's Permanent Fund. After the discovery of oil and the construction of the Trans Alaska Pipeline, the state was debating how to use the anticipated royalties, and wanted the expected revenues to be "out of reach" of the day-to-day government spending, while also generating income for future generations (Alaska Permanent Fund Corporation 2019). In 1976, Alaskans voted 2-1 for a constitutional amendment to create the Alaskan Permanent Fund, in which "twenty-five per cent of all mineral lease rentals, royalties, royalty sale proceeds, federal mineral revenue sharing payments and bonuses received by the State shall be placed in a permanent fund, the principal of which shall be used only for those income-producing investments specifically designated by law as eligible for permanent fund investments" (Alaska Permeant Fund Amendment 1976). Today, the Alaska Permanent funds have assets of more than $66 Billion dollars.

The state of Texas has two of the oldest Sovereign Wealth Funds. The first, the Texas Permanent School Fund (PSF) was created with a $2,000,000 appropriation in 1854, and was "expressly for the benefit of the public schools of Texas." The value of the PSF was $44 billion in 2018. The fund makes a distribution every year, to pay a portion of educational costs in each Texas school district, the cumulative value of the distributions, since 1960, is approximately $28 billion. The fund also provides a guarantee for the bonds issued by local school districts (Texas Education Agency 2019). The second fund, the Permanent University Fund (*PUF*), was enshrined in the Texas constitution in 1876, and funds most of the University of Texas System and the Texas A&M University System. Initially, 1 million acres of land was set aside to support the University of Texas and Texas A&M University systems. The land, now approximately 2.1 million acres, is used to generate income for the PUF. Much of the income comes from oil and gas royalties, with a nontrivial amount of income derived from surface income (grazing leases, wind power generation and commercial vineyard) (University of Texas System 2019). An annual distribution of revenue from the PUF is made available to the universities, with the restriction that the distribution cannot exceed 7% of the market value of the fund's investments. According to the University of Texas System, the PUF funded nearly 1.5 Billion worth of capital projects, between 2004 and 2013 (University of Texas System 2019).

The state of North Dakota has recently created a trust fund based on the rapid increase in crude oil extraction occurring within the state. According to the Energy information Administration (2019), North Dakota ranks second among US states, in the production of crude oil (2017), and holds the second largest proven oil reserves. Developments in extraction techniques, specifically hydraulic fracturing and horizontal drilling, have seen oil production in North Dakota increase tenfold since 2007. As part of this oil boom, in 2010, North Dakota voters established the North Dakota Legacy Fund. The revenues of this Legacy Fund derive from oil and gas taxes—specifically 30% of total revenue derived from taxes on oil and gas production or extraction—obtained by the state are to be transferred to the fund. Over the relatively short period since its creation, the value of the fund has grown to reach a current value of $5.7 billion dollars. Included in the framework was a restriction, which prevented the state from spending either the fund's principal or earnings, until after June 30th 2017. Hageman (2018) reports that recently, some politicians have suggested using some of the money for capital projects, such as infrastructure to help control flooding. However, any withdrawal of the principal requires a two-thirds majority vote in each house of the North Dakota legislature, with a cap of 15% that can be spent in any biennium (Office of the North Dakota State Treasurer 2019). Importantly, after June 2017, the earnings from the Legacy fund are to be transferred to North Dakota's General Fund, and can be used to pay the state's operating expenses. Among the other US state Sovereign Wealth Funds, those established in New Mexico (1958) [2], and Wyoming (1974)[3] are also funded by severance taxes on mineral resources. According to the Sovereign Wealth Fund Institute, there are 78 SWFs around the world (see https://www.swfinstitute.org/sovereign-wealth-fund-rankings/).

Minnesota has two funds that, on the surface, seem to mimic the type of fund being proposed in this paper. Neither fund, however, is an extraction-based state level permanent fund. To provide further clarity, we detail the two funds below, with an emphasis on their revenue sources.

[2] Since 1958, New Mexico has created four Sovereign Wealth Funds through leasing fees on mineral resources and surface lands, severance taxes on the value of minerals extracted, tobacco settlement payments, and state appropriations for protecting water resources (Castilli and Scacciavillania 2012).

[3] In 1974, the Wyoming Legislature established the Permanent Wyoming Mineral Trust Fund.

Minnesota's Environment and Natural Resources Trust Fund

Minnesota has an Environment and Natural Resources Trust Fund (ENRTF) but it is not a statewide extraction-based Sovereign Wealth Fund. The ENRTF is a permanent fund that was started in 1988 "for the public purpose of protection, conservation, preservation, and enhancement of the state's air, water, land, fish, wildlife, and other natural resources" (Legislative-Citizen Commission on Minnesota Resources 2018a). The revenue source has been a minimum of 40% of the net proceeds from the Minnesota State Lottery, which is only constitutionally guaranteed through 2024 (Legislative-Citizen Commission on Minnesota Resources 2018b). The fund has a market value of $1.1 billion USD and has distributed about $500 million dollars for 1,000 projects since inception (Legislative Coordination Commission 2017; Minnesota State Board of Investment 2018).

Two reasons exist why we do not consider the ENRTF as an extraction-based Sovereign Wealth Fund: the funding mechanism and scope of projects. First, there are no ties to non-renewable production or value, which means no ties to the intertemporal extraction trade-off. The use of net lottery proceeds is also an interesting choice given that studies have estimated that Minnesota and other state lottery games are regressive (Oster 2004; Combs et al. 2008). Thus, it could be argued that instead of the ENRTF being funded by extraction companies, it is being funded disproportionately by low-income residents. Second, the ENRTF funds a relatively narrow scope of projects. The name and purpose of the fund limit the type of projects that can be funded compared to the choice, for example, of making allocations to a general fund where it might end up being used for education, health care, and so on. Our point is that given the funding mechanism and scope, we think there is an opportunity for a separate extraction-based permanent fund. Given it was created through a constitutional amendment, is described as permanent, has a sizeable market value, and is funding projects that match its purpose, we envision this fund to continue indefinitely and largely in parallel to any proposed extraction-based fund.

Mineral taxation in Minnesota

We believe it is helpful to get more understanding of Minnesota's mineral taxation system for our analysis, results, and policy implication discussions. In 2015, the Minnesota Office of the Legislative Auditor released its evaluation report entitled "Mineral Taxation" (Minnesota Office of the Legislative Auditor 2015); the report described the mineral taxation system as "…complex and difficult to understand and can lack transparency"(p.xii). To summarize, the focus is placed on the Taconite Production Tax (TPT); the largest revenue generating mining tax.

Historically, TPT taxes account for roughly 70–80% of tax revenue paid on mining activity. In recent years, this has amounted to between $90 and 100 million USD. The TPT is a production-based tax with a statutory rate of $2.52 per taxable metric ton (set in 2013) that is annually adjusted for inflation; for example, the 2017 total rate was $2.701 per taxable ton. Taxable tons are calculated as the average of the most recent three years of production. Although the TPT seems to mimic other state-level severance taxes, the TPT is "…paid in lieu of Ad Valorem (Property) taxes on taconite and lands containing taconite" (p.3; Minnesota Department of Revenue 2017). Revenue collection and redistribution happen mainly at the county and regional level, where mining currently or previously occurred, such that TPT revenues do not flow into the state's general fund. This has important implications for the potential of using TPT revenues to start an extraction based state-level Sovereign Wealth Fund.

Part of the TPT revenues fund the Douglas J. Johnson Economic Protection Trust Fund with the goal of providing funds for economic rehabilitation and diversification in areas where mining currently or previously occurred (Minnesota Office of the Revisor of Statutes 2018). The fund has built a relatively large market value of $163 million USD (2017). This fund, however, should not be considered a statewide extraction based Sovereign Wealth Fund. First, although the TPT is extraction based, it is paid in lieu of property tax. Local stakeholders can always argue that the monies should remain local. This argument has been put forth several times, typically in the context of trying to protect the fund against its use for balancing the state budget (see, for example: Grow 2011; Schutz 2011; Myers 2017). Second, despite the growing balance, the fund is not designated as permanent.[4]

Data, analysis, and results

Various scenarios are constructed to examine what the potential value of an SWF would be. Our analysis is twofold: first, looking backwards, we consider a what-if scenario, in which we estimate an extraction-based SWF started at different points in the past; and second, looking forward, what would the value of a Minnesota SWF be if the state implemented an extraction-based SWF today. A guiding principle through both sections was to make reasonable assumptions in an attempt to capture a range of potential outcomes, and avoid an unending number of iterations. Both backward- and forward-looking scenarios require different data and assumptions, so we will consider each in turn. The discussion section rejoins the two and adds a policy examination. While the data sources

[4] This was confirmed through an email exchange with Sheryl Kochevar, Communications Coordinator for the Minnesota Department of Iron Range Resources and Rehabilitation.

used to support the findings of the study have been referenced throughout the article, the data are available from the corresponding author upon reasonable request.

Backward-looking scenarios—scenario 1: start date 1931

The current value of any SWF will depend on when contributions to the fund began. As Iron ore mining in Minnesota dates back to the late 1800s, this suggests an obvious starting point. However, the United States Geological Survey (USGS) has only been publishing Mineral Yearbooks since the early 1930s. These reports include a wealth of data and analysis; most relevant are the iron ore reports that include Minnesota specific data on amounts of ore produced, shipped, and the shipped total value.[5] The availability of the Mineral Yearbooks restricted the data set from 1931 to 2014.[6]

The early 1930s starting date is supported by the extraction based permanent funds from Texas, which could be considered exceptional for their lengthy history and market value. The Texas Permanent School Fund began in 1854, and has a current market value of $38 billion, while the Permanent University Fund (Texas PUF), started in 1876, has a current market value of approximately $17 billion. The existence of these and other similar funds provided motivation for considering the possibility that a Minnesota extraction-based SWF could have been started long ago.

The revenue generating mechanism in this "what-if" scenario follows that of the Permanent Wyoming Mineral Trust Fund (PWMTF). Article 15, Section 19 of the Wyoming constitution provides "…for an excise tax on the privilege of severing or extracting minerals, of one and one-half percent (1 1/2%) on the value of the gross product extracted" (Maxfield 2009). Wyoming's actual contributions to the PWMTF have exceeded this significantly during some periods; for simplicity, however, 1.5% of the annual shipped total value was used as the annual SWF funding mechanism in the backward-looking scenarios.

Investment returns were another crucial factor in the analysis. To capture a wider range of investment options and potential risk tolerance, the scenarios created utilized investment returns from actual returns of the Texas PUF, bond, and stock investment options. Bonds returns were considered to provide a more risk-averse and likely lower growth bound for our ranges. For stocks, the S&P index was used for its combination of market breadth and to provide returns for the entire period 1931–2014. The options were expanded beyond these three to include various mixes of bonds and stocks. Additional return options allowed for PUF returns in the early years and then switching to either the returns from the Wyoming or Alaska permanent funds.

We keep the analysis tractable by evaluating eight investment options for the fund's principal (see footnote for investment return data sources):[7]

A. 100% investment in one-year bonds
B. 100% investment in the S&P index
C. 25% investment increments of the two above: 25% bond, 75% S&P
D. 50% bond, 50% S&P
E. 75% bond, 25% S&P
F. Same estimated annual returns as the Texas PUF
G. Texas PUF estimated annual returns until 1976 then switch to estimated annual returns from the Permanent Wyoming Mineral Trust Fund (PWMTF) through 2014
H. Texas PUF estimated annual returns until 1978 then switch to annual returns from the Alaska Permanent Fund through 2014

We also consider two alternative fund goals. First, we used a simple fund goal of growing the principal (no withdrawals). Second, the fund principal was allowed to grow to $1 billion

[5] In early reports, average values at the mine were available specifically for Minnesota; reports starting in the 1960s and later, however, only report average value at the mine by district. A check of the differences indicated that in some years averaged shipped value and average value at the mines were the same. When more specific prices were available (e.g., in 1951) based on product, the average shipped value was between the average value at the mines for the two products direct iron ore and iron ore concentrates. As the average shipped values are close the average value at the mines and Minnesota specific values are available for more years of the study period (1931–2014) that measure was the focus of the extraction value-based scenarios. Also, although amounts produced and shipped are different for the same year, the differences are relatively small; the root mean squared difference is about 1.2 million metric tons, only 2.6% of the averaged shipped metric ton value over this data range.

[6] Over the last decade of the dataset (2004–14), we estimated shipped total value due to disclosure issues. In years 2004–2013, a total value of Michigan and Minnesota shipments was presented along with individual state tonnages. An average value per metric ton for Michigan and Minnesota was calculated and multiplied by the tonnage from Minnesota. Since Minnesota has considerably larger tonnage than Michigan (average ratio 3.21:1), this shipped total value estimation should be reasonable. In 2014, a Minnesota average value of production was presented in the Mineral Yearbook, which was multiplied by tonnage shipped to get the estimate of shipped total value.

[7] Data for one-year bond interest rate was retrieved from Robert Shiller's Online Data website (http://www.econ.yale.edu/~shiller/data.htm) in the series entitled "Long term stock, bond, interest rate and consumption data". S&P returns are from the same source, with the return being calculated as the annual percentage change in the S&P Composite Stock Price Index. Texas PUF data were retrieved by submitting an open-records request to the University of Texas Investment Management Company (UTIMCO) (https://www.utimco.org/scripts/internet/openrecords.asp); Compliance Specialist Michelle Kraal responded with Texas PUF data from 1923-2016 and estimated annual returns were calculated by dividing the net investment return by the prior year's ending value. PWMTF estimated annual returns were calculated using data retrieved from the Wyoming Taxpayers Association website (www.wyotax.org/publications.aspx) in the report entitled "The Wyoming Permanent Mineral Trust Fund - Facts, FAQs, & Historical Accounting"; estimated annual returns were calculated by dividing investment income by the prior year's ending balance.

before allowing for the annual investment income to be withdrawn to another account such as a state's general fund.[8]

Backward-looking scenarios—scenario 2: start date 1976

Many of the state funds were initiated in the mid-1970s, which suggests an additional starting point to be considered. Thus, two separate starting dates are considered in the analysis. The shorter time horizon is intended to mimic the start dates of several US state permanent funds. The Alaska Permanent Fund, the Montana Coal Severance Tax Permanent Fund, the New Mexico Severance Tax Permanent Fund and the Wyoming Permanent Mineral Trust Fund are all extraction-based funds created in the mid-1970s.

Backward-looking scenarios—results

To summarize, we calculated scenarios using a Wyoming-style mechanism of 1.5% of value severance tax with eight investment options, two fund goals, and two alternative starting points (1931 and 1976). The results of the 32 scenarios are presented in Table 1. For the long time-horizon (1931 start), the 1.5% of value tax leads to a cumulative $1.25 billion just in extraction contributions. For reference, Minnesota's general fund expenditures in FY 2014 were about $19.35 billion (Minnesota Management and Budget 2020).

After including investment alternatives under the principal growth goal, the range of ending balances (2014) for the SWF was [$6.6 billion, $27.1 billion] or between 34 and 140% of 2014 state general fund expenditures. If the SWF was allowed to grow to $1 billion in principal and then the investment income was allowed to be transferred to another account (e.g., general fund), the scenario with the smallest sum of the two accounts is the 1-year bond with a $2.0 billion SWF principal and $2.1 billion in cumulative general fund contributions (about 11% of 2014 state general fund expenditures) while the scenario with the largest sum of the two accounts is the S&P combined with Alaska returns which generates a $1.6 billion SWF principal and $4.9 billion in cumulative general fund contributions (about 25% of 2014 state general fund expenditures).

For the short time-horizon (1976 start), the 1.5% of value tax leads to a cumulative $1.02 billion just in extraction contributions. After including investment alternatives under the principal growth goal, the range of ending balances (2014) for the SWF was [$2.3 billion, $7.6 billion] or between 12 and 39% of 2014 state General Fund expenditures. If the SWF was allowed to grow to $1 billion in principal and then the investment income was allowed to be transferred to another account (e.g., general fund), the scenario with the smallest sum of the two accounts is the 1-year bond with a $1.6 billion SWF principal and $0.5 billion in cumulative general fund contributions (about 3% of 2014 state general fund expenditures) while the scenario with the largest sum of the two accounts is the Texas PUF which generates a $1.33 billion SWF principal and $2.53 billion in cumulative general fund contributions (about 13% of 2014 state general fund expenditures).

We acknowledge that the 1.5% of value tax could have production implications. Rather than estimate the potential production effects of the additional tax through historical observations that span structural changes in the industry (e.g., switch from iron ore to taconite pellets from about 1960-1980, large efficiency gains in the 1980s), we estimated what percent of actual TPT collections would have been necessary to generate similar revenue and returns as a 1.5% of value tax. The TPT is only collected on taconite produced (not iron ore) such that production years prior to 1951 resulted in negligible tax generation. TPT collection amounts from 1951 to 2014 were used (Minnesota Department of Revenue 2020).[9] Due to the later start of the TPT, and the TPT rate being lower than 1.5% of the implied value per ton until the early 1970s, it would take about 80% of actual TPT collections to produce similar principal balances in 2014 as those from the early start scenario with a 1.5% of value tax. If the policy had started in 1976, about 30% of TPT collections would be needed to generate similar principal balances in 2014 as those from the later start scenario with a 1.5% of value tax. The large difference in the needed percentages (80 vs. 30%) is mainly due to the TPT rate catching and significantly passing 1.5% of the implied value per ton after the early 1970s. For example, the TPT rate was nearly twice as high as 1.5% of the implied value per ton in 2014 ($2.56 vs. $1.29 per metric ton). From a practical standpoint, these percentages are too large to take from actual TPT collections, given that much of the TPT revenue flows to the county and regional community where production occurs.

Forward-looking scenarios

While instructive, the backward scenarios represent what could have been. Our attention now turns to a forward-looking analysis, and to what might yet be. In the prior section, the conclusion was that shifting a large proportion of TPT dollars to an SWF is impractical based on historic rates. Therefore, we explore increasing the TPT rate as a method of

[8] Some investment options incur losses for given years in the dataset. It is assumed that investment losses cannot be taken from the general fund. The losses penalize the fund principal not the general fund contributions; that is, if there is an investment loss the general fund contribution is assumed to equal $0 for that year and the investment loss decreases the principal of the SWF. Note, this strategy does not protect the principal and it is possible that the principal can decrease below the $1 billion value that triggered this strategy to begin.

[9] Estimates for each year 1951–1954 were obtained by subtracting 1955 collections from the total collections during production years 1951–55 and then creating an average tonnage rate for the four years of $0.0576 per long ton.

Table 1 Backward-looking results as of 2014 with 1.5% of value tax ($ billion USD)

	Investment Portfolio	A	B	C	D	E	F	G	H
Start Year	Short Description	1 Yr Bond	S&P	25% B, 75% S&P	50% B, 50% S&P	75% B, 25% S&P	S&P + WY	S&P + AK	Texas PUF
1931	Principal[a]	$6.6	$17	$14.9	$12.1	$9.2	$11.2	$27.1	$22.5
1931	Principal; GF[b]	$2.0;$2.1	$0.9; $4	$1.2; $3.9	$1.5; $3.5	$1.7; $2.8	$1.9; $3.0	$1.6; $4.9	$1.5; $4.4
1976	Principal	$2.3	$5.3	$4.6	$3.8	$3.0	$3.8	$6.9	$7.6
1976	Principal; GF	$1.6; $0.5	$0.9; $2.4	$1.1; $2.1	$1.3; $1.6	$1.5; $1.2	$1.7; $1.3	$1.4; $2.4	$1.3; $2.5

[a] Principal = ending balance of SWF in 2014, [b] GF = hypothetical cumulative contributions to MN general fund

funding the SWF. However, increasing the rate could create a production effect.

The production effect from the increased TPT rate was estimated econometrically in order to understand its potential effects on the industry. If the production effect was very large, production and tax revenues would be very low and it would challenge the viability of creating an SWF. If the effect was smaller and statistically significant, lower production amounts would lead to lower SWF revenues each year, thereby effecting the cumulative balance of the SWF and its ability to provide an important alternative revenue stream. Therefore, estimating the production effect can aid in the validity of the hypothetical SWF balance.

To estimate the production effect, the supply and demand of US iron ore were econometrically estimated using an SURE framework. The real TPT rate was found to be negatively correlated and statistically significant in the supply equation of the model. We then use the coefficient to estimate the potential production loss from increasing the rate; the point estimate suggests a production loss of 4.4%.

After estimating the production effect, economically recoverable mineral reserve estimates were used to make predictions about the potential size and impact of an SWF looking-forward. Picking a time horizon is arbitrary since estimated mine life varies and the potential copper-nickel mines are not fully approved (there would be a delay before production could begin). To keep things straightforward, the potential value of an SWF at the end-of-year 2050 was estimated.

Based on feasibility studies, we use back of the envelope calculations to consider the potential contributions from proposed copper-nickel mining sites. Under reasonable investment returns, these activities could add over a billion dollars to an SWF, which represents about 5% of 2014 state general funds contributions.

Taconite

A logical possibility is to add 1.5% of value to each year's TPT amount. The TPT rate already changes annually based on the prior year's percentage change in the Gross Domestic Product Implicit Price Deflator inflation adjustment (Minnesota Department of Revenue 2017). Similarly, an estimated or recent price could be used to determine the additional amount to add to the TPT each year to approximate a 1.5% of value tax. Doing so would simplify things for producers, they would pay a known TPT rate per ton. After collection, the amounts would be separated into the portion for the SWF and the typical TPT distributions.

Given a fixed and known TPT rate, excise tax theory can help to estimate the production and dead weight loss implications of the higher tax rate. One method is to estimate the supply and demand function of iron ore pellets and determine how the tax rate effects production. Due to the structural changes from the shift of iron ore to taconite pellets (1960–1980) and large efficiency gains during the 1980s, starting the dataset in the early 1990s makes sense. Tons per worker hour stays at or above 3.9 starting in 1993, so that criterion set the starting year, providing a dataset that spans the years 1993–2016.

Estimating the production effect from a taconite tax increase—supply estimation

Monthly production data were desired to boost the number of observations. The Board of Governors of the Federal Reserve System (BGFRS) publishes an unadjusted monthly iron ore mining industrial production index; this was used as an estimate of quantity supplied (BGFRS 2019a). While these data are at the US level, Minnesota averaged about 75% of US production over these years.

Candidate supply independent variables came from the literature and knowledge of indefinite mine closures and recessions. While considering the supply side, it is important to note that, in the USA, a significant proportion of mine production is considered captive to the companies that own them (Barrington 1992; p. XXXIII):

> The North American iron ore market is rather different: a very significant proportion of iron ore comes from captive mines owned by the steel companies… Pellets

> are "sold" by the mines to their owners at published "Lower Lakes" prices which are quoted by the various companies (it must be said that these Lower Lakes prices bear little relation to world market prices and owe more to domestic considerations)… The transparency of the North American market is very much less than elsewhere.

Liebeler et al. (1986) estimated that the proportion of pellet consumption considered captive was over 80% between 1983 and 1985. This integration makes choosing an appropriate price variable less obvious since it is unclear whether this market responds to global iron ore prices, something similar to "Lower Lakes" prices, or steel production costs for US producers (Liebeler et al. 1986, A-41):

> Because iron ore pellets are characterized by a very low value-to-weight ratio, transportation costs are significant in all shipments of iron ore. Most of the iron ore pellets used in the United States are consumed by steel companies located in or near Chicago, Cleveland, or Pittsburgh. U.S. producers have an inland transportation cost advantage to the lower Great Lakes,… [excludes Pittsburgh].

Several price variables are considered. The USGS Mineral Commodity Summaries publish an annual mine reported variable called value.[10] The World Bank publishes a monthly cost and freight (CFR) spot price as part of its Commodity Markets data (World Bank 2019). We also consider whether iron ore prices are best reflected in the monthly United States Bureau of Labor Statistics (USBLS) Producer Price Index for Steel Mill Products (United States Bureau of Labor Statistics (USBLS) 2019a). The USBLS also publishes a PPI for Iron Ore Mining; this was used as a denominator to create real prices for each of the three variables listed above (United States Bureau of Labor Statistics (USBLS) 2019b).

Other supply variables candidates came from the literature estimating iron ore supply and demand at the country, region, or world level. Labson et al. (1995) utilized a lagged dependent variable (quantity) to "…capture partial adjustment…" (p.41). Priovolos (1987) used a lagged utilization rate, OPEC price, and export unit value. Zhu (2012) included a lagged price, interest rates, and a time trend. All included dummy variables to capture various supply shocks based on the dates from their regression data. For our purposes, the supply shocks included the indefinite shut-down of the Minnesota LTV mine in 2001 and the indefinite shut-down of the Michigan Empire mine in September 2016. Also included as dummy variables were recession events from late 2008 to the first quarter of 2010 and a separate event throughout 2016 to capture the manufacturing mini-recesson.[11] We considered the literature, while also factoring in data availability and multicolinearity when choosing covariates for the final regression models.[12]

All regression analyses were performed using NLOGIT 5 statistical software. Unit root tests were performed on both dependent variable production indexes to check for stationarity. AIC and RMSE criteria indicated that monthly lag models outperformed 12 month lag models for both production indices. The iron ore production index (quantity supplied) suggested up to two statistically significant monthly lags. All models of the Phillips-Perron test (PPT) of a unit root were rejected at the 1% level for up to five monthly lags. When controlling for other covariates, one lag was statistically significant and kept in the model.

Therefore, the estimated linear supply functions followed the form:

$$Q_t^S = \beta_0 + \beta_1 Q_{t-1}^S + \beta_2 \text{ Real Price}_t + \beta_3 \text{ Real TPT Rate}_t + \beta_4 \text{ LTV Closure}_t + \beta_5 \text{ Empire Closure}_t + \beta_6\, 2009_t + \beta_7\, 2016_t + \sum_{i=8}^{18} \beta_i \text{ Month}_t + \varepsilon_t^S \quad (1)$$

where:

Q_t^S	unadjusted monthly iron ore mining industrial production index
Q_{t-1}^S	one month lag of unadjusted monthly iron ore mining industrial production index
Real Price$_t$	Real Value = (annual USGS value)/(monthly PPI Iron Ore Mining),
or Real PPI SMP	(monthly PPI for Steel Mill Products)/(monthly PPI Iron Ore Mining)
Real TPT Rate$_t$	(annual TPT Rate)/(monthly PPI Iron Ore Mining)
LTV Closure$_t$	dummy variable for months after the indefinite shut-down of the LTV mine in 2001
Empire Closure$_t$	dummy variable for months after the indefinite shut-down of the Empire mine in 2016

[10] According to Mineral Commodity Specialist Christopher Tuck, these values are estimates subject to revisions over time. Therefore, when possible, the values used are those from five years prior to the report year.

[11] 2016 was recently referred to as a mini-recession, especially in manufacturing (Irwin 2018).

[12] Using price lag variables as replacements, for their respective price, often leads to worse or similar model performance. In addition, model coefficients were regularly inconsistent (wrong variable signs or statistical insignificance). The TPT rate coefficient in these models was similar or higher in magnitude (lower in absolute value), implying a smaller production effect from a higher TPT rate compared to models without a lagged price. A log-log version of Model 1 (see Table 2) lead to higher standard errors for the supply and demand equations. Log-log versions of models 1-3 lead to insignificant TPT rate coefficients with smaller production impacts.

2009_t	dummy variable used as a control for Great Recession months (=1 from Dec. 2008 - March 2010)
2016_t	dummy variable used as a control for manufacturing mini-recession months (=1 from Jan. 2016 – Dec. 2016)
Month_t	monthly dummy variables (January baseline)

Estimating the production effect from a taconite tax increase—demand estimation

We were not able to obtain monthly apparent consumption data for iron ore pellets; however, iron ore pellets are a primary input in the production of pig iron via blast furnaces (see, for example, ArcelorMittal 2019). Therefore, the BGFRS unadjusted monthly Pig Iron Industrial Production Index was used as an estimate of quantity demanded for iron ore pellets (Board of Governors of the Federal Reserve System (US) 2019b). Based on lag only models for the unit root test, the pig iron production index (quantity demanded) suggested one statistically significant monthly lag. However, only the basic PPT model was rejected and at the 5% level. Yet, when allowing for a second monthly lag, all models of the PPT were rejected at the 1% level. When controlling for other covariates, two lags were significant or borderline significant in most models; therefore, two lags were included in the demand models estimating the pig iron production index due to their typical significance and reduced risk of a unit root.

One unavoidable structural change occurring in the data set is the ongoing trend toward a higher percentage of US crude steel being produced using Electric Arc Furnaces (EAF) versus traditional blast furnaces. EAFs rely much more heavily on scrap steel as opposed to iron ore pellets. According to Madias (2014, p.273), "In the developed world, 100% steel scrap is the most common charge." Similarly, the International Iron Metallics Association (2017) reports that pig iron on average makes up 5–10% of the charge but, if scrap is scarce, it can be as high as 60%. We used the World Steel Association annual Steel Statistical Yearbook series to provide the annual percentage of EAF production in the USA (World Steel Association 2019). In addition, we retrieved the unadjusted monthly data USBLS PPI for Material Recyclers: Heavy Melting Scrap as an indication of scrap price for EAF production (United States Bureau of Labor Statistics (USBLS) 2019c). Therefore, inclusion of these variables will likely factor out a significant amount of the effect of EAF production on pig iron production thereby increasing the reliability of the price variable to consider iron ore pellet demand.

Zhu (2012) adds world GDP to the world demand model for iron ore as a measure of income. However, US EAF percentage and world GDP per capita are highly correlated with the coefficient equaling 0.98. Consequently, GDP measures were excluded from the demand equations due to multicolinearity concerns.

Therefore, the estimated linear demand functions followed the form:

$$\begin{aligned} Q_t^D = {} & \beta_0 + \beta_1 Q_{t-1}^D + \beta_2 Q_{t-2}^D + \beta_3\, Price_t \\ & + \beta_4\, \text{Scrap Price}_t + \beta_5\, \text{USEAF PCT}_t \\ & + \beta_6\, LTV\ \text{Closure}_t + \beta_7\, \text{Empire Closure}_t \\ & + \beta_8\, 2009_t + \beta_9\, 2016_t + \textstyle\sum_{i=10}^{20} \beta_i\, \text{Month}_t + \varepsilon_t^D \end{aligned} \quad (2)$$

where:

Q_t^D	unadjusted monthly Pig Iron Industrial Production Index
Q_{t-1}^D	one month lag of unadjusted monthly Pig Iron Industrial Production Index
Q_{t-2}^D	two month lag of unadjusted monthly Pig Iron Industrial Production Index
Price_t	Nominal Value (Annual USGS value),
or Real Value	(Nominal Value)/(monthly PPI Iron Ore Mining),
or Real PPI SMP	(monthly PPI for Steel Mill Products)/(monthly PPI Iron Ore Mining)
Scrap Price_t	PPI Scrap (PPI for Material Recyclers: Heavy Melting Scrap)
or Real Scrap Price	(PPI Scrap)/(monthly PPI Iron Ore Mining)
USEAF PCT_t	annual percentage of Electric Arc Furnace production in the United States
LTV Closure_t	dummy variable for months after the indefinite shut-down of the LTV mine in 2001
Empire Closure_t	dummy variable for months after the indefinite shut-down of the Empire mine in 2016
2009_t	dummy variable used as a control for Great Recession months (= 1 from Dec. 2008 – March 2010)
2016_t	dummy variable used as a control for manufacturing mini-recession months(= 1 from Jan. 2016 – Dec. 2016)
Month_t	monthly dummy variables (January baseline)

Estimating the production effect from a taconite tax increase—regression results and analysis

Due to the feature of captured supply, and the ability to store inventory of iron ore pellets, we chose not to impose equilibrium in the statistical estimates (e.g., through a simultaneous equation framework). Instead, the supply and demand equations were allowed to be linked through freely correlated disturbances in a seemingly unrelated linear regression (SURE) generalized least squares framework. We present three alternative models that have similar overall model performance in Table 2.

The coefficients are largely consistent with prior expectations: the supply functions have positive price coefficients (although insignificant in Model 3) and negative tax rate coefficients. Regression results imply that supply is not very responsive to price; our results estimate price elasticities of supply of 0.14 using the real PPI for steel mill products and 0.009 using real value as price measures. We were not able to find recent estimates of the United States or North American iron ore supply elasticities for comparison, this is not surprising as the US share of world production has continued to fall to about 2% and the literature has focused on larger players such as Australia and China. However, our supply elasticity estimates are in line with regional estimates from Priovolos (1987) and Labson et al. (1995) of 0.04, and are contextually consistent with a world estimate of 0.45 from Zhu (2012). The demand functions have negative price coefficients, positive cross-price coefficients for scrap, and a negative relationship with the US EAF percentage. The events coefficients are consistently negative with the exception of the Empire mine; this is likely due to data restrictions from other variables leaving only four months after the indefinite shut-down in the dataset.

Since the models seemed reliable, the next step was to calculate the production effect from an increase in the TPT rate. The value of the real TPT rate equals the TPT rate divided by the PPI for Iron Ore Mining. The nominal TPT rate equaled $2.708 per metric ton, while the average PPI value equaled 135.4 in 2018. Therefore, an estimate of a recent value for the real TPT rate = $2.708/135.4 = $0.02 per metric ton. The USGS nominal value of iron ore in 2018 was estimated at $82 per metric ton.[13] Adding 1.5% of value would increase the TPT rate by $1.23 ($82*0.015), making the new total rate equal to $3.938 per metric ton and the real TPT rate = $0.029 per metric ton. Multiplying the change in the real TPT rate (0.009) by the point estimate of − 440 (from Model 1 in Table 2) led to an estimate of the change in the iron ore production index of − 4.0. The average value of the production index in 2018 was 95.45; therefore, the percent change in the index would be − 4.14%. Using a relatively recent and stable annual production period of 2011–2014, average Minnesota production equaled 41.2 million metric tons (range = [39.4, 42.2]). A decrease of 4.14% would equal about 1.71 fewer metric tons annually, implying a new expected annual production amount of about 39.5 million.

Excise tax theory implies that the dollar value of the wedge created from a tax is the tax rate (see, for example; Varian 1999). Based on our linear regression estimations, the current TPT rate creates dead weight loss (DWL) from a production decrease. Adding the 1.5% of value tax to the current TPT rate is expected to create an addition amount of DWL; a visual abstraction would be the area of a DWL trapezoid created by subtracting an original tax rate DWL triangle (smaller) from a higher tax rate DWL triangle (larger). Therefore, an estimate of the additional DWL can be found by taking the average of the tax rates and multiplying by the quantity change (formula for the area of trapezoid), which equals $5.68 million annually. An estimate of the additional tax revenue generated would be $44 million annually; the new tax revenue of $156 million ($3.938/MT * 39.5 million metric tons) minus the old tax revenue of $112 million ($2.708/MT * 41.2 million metric tons). Therefore, the significant additional total revenue at the higher tax rate is expected to help keep the additional DWL at a reasonable level. To help put the extra $5.68 million per year DWL into context, a rough estimate of price and cost per metric ton in 2018 was $104 and $79 (Cleveland-Cliffs, Inc 2019). If the margin of about $25 were applied to all Minnesota production of about 40 million metric tons per year, the resulting back-of-the-envelope estimate of profit would be $1 billion per year. (Admittedly 2018 seems to have been a good year).

The range for the real TPT rate in the dataset is [0.0128, 0.0251]. As calculated above, adding the 1.5% of value tax would increase the real rate to 0.029. Since this lies outside the range, we consider the possibility that the effect will be stronger. The lowest magnitude coefficient from the 95% confidence intervals of the three models (presented in Table 2) equals − 888. Using similar methods as above, the iron ore production index would decrease 8.2%, which would amount to about a 3.38 million metric ton annual decrease for Minnesota production and $11.4 million in DWL. The additional annual tax revenue would be about $37 million.

In summary, we estimated the supply and demand of North American iron ore. The results were used to generate estimates of the potential production loss due to adding 1.5% of value to the existing TPT tax. The point estimate suggests a production loss of 4.14%. Using the lower bound of a confidence interval, the loss is estimated at 8.2%. While incurring production losses and DWL is not desirable, we do not consider these loss amounts to be overwhelming and return to the initial motivation of estimating the potential size of a Sovereign Wealth Fund in year 2050 based on the 1.5% of value funding mechanism, recoverable reserves, potential price paths, and possible investment returns.

Estimating future additional tax revenue from an increase in the TPT rate

Estimating forward-looking tax revenues required data on the amount of iron ore reserves and assumptions regarding price paths. The taconite firms operating Minnesota mines are

[13] Using the World Bank spot price would lead to a smaller impact since the average 2018 price was $69.75 per metric ton.

Table 2 SURE regression results (March 1993–Dec 2016)

Quantity Supplied: Dep Var = Monthly FRED Iron Ore Mining Production Index			
	Model 1	Model 2	Model 3
Constant	40.3***	42.0***	46.1***
	(8.71)	(8.73)	(9.22)
1 Month Lag	0.608***	0.605***	0.633***
	(0.0460)	(0.0459)	(0.0452)
Real Value			1.12
			(4.78)
Real PPI Steel Mill Products	7.83**	7.13**	
	(3.33)	(3.36)	
Real TPT Rate	− 440**	− 463**	− 411*
	(217)	(217)	(238)
Event LTV	− 9.48***	− 9.56***	− 8.37***
	(1.78)	(1.78)	(1.76)
Event Empire	1.29	1.31	1.77
	(5.09)	(5.09)	(5.12)
Event 2009	− 15.8***	− 16.1***	− 16.1***
	(2.93)	(2.93)	(2.99)
Event 2016	− 7.12**	− 7.10	− 6.77**
	(3.12)	(3.12)	(3.24)
Feb	5.89**	5.88**	6.09**
	(2.41)	(2.41)	(2.43)
March	4.36*	4.35*	4.49*
	(2.38)	(2.38)	(2.39)
April	3.03	3.00	3.12
	(2.39)	(2.39)	(2.41)
May	11.7***	11.7***	11.85***
	(2.39)	(2.39)	(2.41)
June	4.11*	4.10*	4.10*
	(2.38)	(2.37)	(2.39)
July	7.44***	7.43***	7.50***
	(2.37)	(2.37)	(2.39)
Aug	3.06	3.06	3.14
	(2.37)	(2.37)	(2.39)
Sept	7.35***	7.35***	7.55***
	(2.39)	(2.38)	(2.40)
Oct	6.44***	6.45***	6.56***
	(2.38)	(2.38)	(2.40)
Nov	7.22***	7.22***	7.23***
	(2.38)	(2.38)	(2.40)
Dec	1.51	1.52	1.46
	(2.39)	(2.39)	(2.41)
Std. error	8.12	8.12	8.18
Autocorrelation	0.020	0.0225	0.0118
Quantity Demand: Dep Var = Monthly FRED Pig Iron Production Index			
	Model 1	Model 2	Model 3
Constant	71.2***	67.4***	67.5***
	(9.72)	(9.70)	(9.20)
1 Month Lag	0.738***	0.834***	0.758***
	(0.0604)	(0.0595)	(0.0601)
2 Month Lag	− 0.126**	− 0.0939	− .135**
	(0.0552)	(0.0586)	(0.0560)
Nominal Value	− 0.260***		
	(0.0488)		
Real Value			− 35.6***
			(7.42)
Real PPI Steel Mill Products		− 6.63**	
		(3.31)	
PPI Scrap	0.0421***		
	(0.00646)		
Real Scrap Price		3.02***	4.96***
		(0.729)	(0.817)
US EAF Pct.	− 0.421***	− 0.670***	− 0.330**
	(0.149)	(0.131)	(0.144)
Event LTV	− 5.27***	− 1.02	− 5.47***
	(1.63)	(1.50)	(1.67)
Event Empire	− 1.60	0.00578	− 1.60
	(3.36)	(3.49)	(3.39)
Event 2009	− 1.47	− 4.49**	− 2.43
	(1.88)	(1.86)	(1.86)
Event 2016	− 4.28*	− 1.72	− 4.25*
	(2.37)	(2.38)	(2.29)
Feb	3.00*	2.90*	2.90*
	(1.58)	(1.65)	(1.59)
March	0.643	0.279	0.463
	(1.59)	(1.65)	(1.60)
April	− 2.36	− 2.72*	− 2.50
	(1.57)	(1.63)	(1.58)
May	− 0.285	− 0.370	− 0.368
	(1.56)	(1.63)	(1.57)
June	− 0.0645	− 0.238	− 0.217
	(1.57)	(1.63)	(1.58)
July	− 3.45**	− 3.60**	− 3.65**
	(1.57)	(1.63)	(1.58)
Aug	0.958	1.20	0.872
	(1.56)	(1.62)	(1.57)
Sept	− 0.148	− 0.152	− 0.324
	(1.58)	(1.65)	(1.59)
Oct	− 3.32**	− 3.86**	− 3.59**
	(1.58)	(1.65)	(1.59)
Nov	− 1.17	− 1.59	− 1.46
	(1.58)	(1.64)	(1.58)
Dec	− 2.97*	− 2.88*	− 3.12**
	(1.57)	(1.63)	(1.58)
Std. error	5.34	5.56	5.38
Autocorrelation	0.0095	0.0010	0.0086
Model-level	Model 1	Model 2	Model 3
n	286	286	286
Log-likelihood	− 1886	− 1897	− 1891

***, **, * = significant at 1%, 5%, 10% level

public; they disclose some measures of reserve estimates in annual financial reporting. The companies are careful to note that the estimates used meet either the Canadian National Instrument 43-101 or SEC Industry Standard Guide 7 procedure expectations; however, these formal estimate reviews are not undertaken every year so the year of the formal review should be kept in mind when trying to discern the meaning of the annual financial reporting numbers. It is also important to understand that reserve estimates are dynamic and depend on factors such as output price, extraction technology, and deposit mapping technology. Consider these two illustrative examples:

Cleveland Cliff's United Taconite mine; salable reserve estimates increased 72% from 2015 to 2016 despite a trend of falling output prices (p. 37, 2016 Cleveland Cliff's Annual report):

> A new economic reserve estimate was completed for United Taconite in 2016. Based on this analysis, saleable product reserves increased by 115 million long tons as a result of an updated life-of-mine plan and production schedule that now include previously developed mine areas south of our current operations commonly referred to as the South Pit. This area had previously been considered as mineralized material until an economically scheduled mine plan was developed.

U.S. Steel Keetac and Minntac reserves were adjusted in opposite directions after their most recent formal reviews (p. F-58, 2017 U.S. Steel Annual report):

> The most recent such review for our Keetac operating mine was completed in 2013 and resulted in an increase in the proven and probable reserves primarily due to additional exploration drilling and development of an economic computerized mine plan. The most recent review for our Minntac operating mine was conducted in 2005 and led U. S. Steel to reduce its determination of proven and probable reserves mainly due to excluding areas where sampling and measurement did not meet its new 600-foot drill spacing standard, based on updated geostatistical studies.

Table 3 provides the taconite reserves data necessary to consider forward-looking scenarios. The estimated mine life varies considerably, and the 2050 time-line is meant only for the purpose of analysis within our research. Several mines are expected to cease production before 2050. Total production for the state falls considerably in 2023 with the expiration of Hibbing Taconite and again in 2047 with the expiration of Minntac. 2050 total production levels are approximately 40% of current levels.

Forward looking scenarios depend on price paths but creating a price path is extremely challenging given demand, competition, and political uncertainty. The 2018 Mineral Commodity Summary supplies some evidence of iron ore price volatility listing prices of $133/metric ton in October 2013, $59/ton in October 2016, $89/ton in February 2017, and $62/ton in October 2017 (USGS). We acknowledge volatility by having the scenarios include a low ($60) and high price ($100) option, noting that the SWF value would likely fall in-between.

Evidence suggests that taconite producers will produce at $60/ dry metric ton but may shut-down at prices closer to $50. U.S. Steel idled the Keetac plant in May 2015 after April prices of about $52; they re-opened in early 2017 with prices close to $80 (United States Steel Corp 2018; IndexMundi 2018); however, prices had been closer to $60 as recently as October 2016. Cleveland-Cliffs temporarily shut-down United Taconite in August 2015 after prices in July of about $52; they re-opened in August 2016 after July prices of about $57 (Cleveland-Cliffs, Inc 2017; IndexMundi 2018). Cleveland-Cliffs also idled the Northshore mine in late November 2015, the November price was about $47; they re-opened in May 2016 after April prices around $61 (Cleveland-Cliffs, Inc 2017; IndexMundi 2018). Note the other mines produced relatively close to capacity in 2015 and 2016, which suggests that $60 seems to be a reasonable low price and full production scenario.

On the high end, iron ore prices have approached $200 several times in the last dozen years. The most recent occasion was in February 2011 at $187. Another noticeable peak in price occurred in February 2013 when prices were near $155. More recently, prices increased from $69 in December 2018 to $120 in July 2019. For our purposes, the high price was set at $100.

Inflation was considered in the future scenarios. The average annual inflation rate in the CPI (All Urban Consumers, a.k.a. CPI-U) between 2000 and 2018 was 2% (United States Bureau of Labor Statistics (USBLS) 2019d); using a longer horizon, the average annual inflation rate was 3.7% between 1960 and 2018. Therefore, we used two values (2% and 4%) to generate scenarios for the 2050 ending balance. With 2% inflation, the $60 price grows to $113, while the $100 price grows to $188 in 2050. With 4% inflation, the $60 price grows to $210, while the $100 price grows to $351 in 2050.

Investment returns are important in determining the 2050 ending balance as well. The average investment return in the Texas PUF from 1931 to 2014 was 6.5%. The average investment return in the Alaska Permanent Fund from 1978 to 2014 was 10%. These average returns informed the decision to use a 5% as a low value investment return and 10% as the high.

Table 4 offers a variety of scenarios to provide some sensitivity analysis. As expected, the results are highly dependent on assumptions. If we change one variable at a time, the additional TPT tax percentage, production loss percentage, or starting price result in equiproportionate changes in ending balance. For example, a tax percentage 67% of the added base rate (e.g., 1.5% to 1%) leads to 67% of the base rate 2050 ending balance, and a tax percentage 133% of the added base rate (e.g., 1.5% to 2%) leads to 133% of the base rate ending balance in 2050. Changing only the investment return leads to a more complex relationship with ending balance because the same amount of new revenue is added to each stream in each year (and a different amount across years). For example, with

Table 3 Taconite mine reserves (million metric tons)

	Annual report year	Formal reserve analysis year	Total reserves	Saleable proven & probable reserves	2017 saleable production	Annual capacity	Estimated mine life; closure year
ArcelorMittal (AM); Minorca	2017; Reserves and Resources (p. 287-288)	?	**110**	37.7	**2.9**	2.9	2030
Cleveland-Cliffs (C-C); Northshore Mining	2017; Mineral Reserves (p. 32, 35-36)	**2015**	**806**	**260**	**5.4**	**6.1**	2060
Cleveland-Cliffs; United Taconite	2017; Mineral Reserves (p. 32, 35-36)	**2016**	**842**	**269**	**4.9**	**5.5**	2067
Joint - Hibbing Taconite	AM 2017; C-C 2017	**2015**	**182**	**48 (C-C)**	**7.8 (C-C)**	**8.1 (C-C)**	2023
U.S. Steel; Minntac	2017; Mineral Reserves (p. F-58)	**2005**	?	**435**[a]	**14.5**	**14.5**[b]	2047
U.S. Steel; Keetac	2017; Mineral Reserves (p. F-58)	**2013**	?	**345**[a]	**4.6**	**5.4**[b]	2092

Bold indicates numbers taken directly from the reports, without bold are inferred from those provided

[a] It was confirmed in an email on 8/9/2018 from Meghan Cox (Manager of External Relations for U.S. Steel) that the proven and probable reserve amounts listed are in saleable pellet tons

[b] Estimates provided from U.S. Steel website: https://www.ussteel.com/locations/minntac

an inflation rate of 2%, the ratio of ending balances for the 5% investment return is about 2.4, while with a 10% return, the ratio is about 2.75. The inflation rate also seems to have a complex relationship with ending balance. When the investment return is 5%, the ratio of ending balances for the 4% inflation rate compared to the 2% inflation rate is about 1.28. When the investment return is 10%, the ratio of ending balances for the 4% inflation rate compared to the 2% inflation rate is about 1.20.

To discuss a few specific outcomes, we rely on the Federal Reserve's inflation target of 2% (and the average annual inflation rate of 2.0% in the CPI-U between 2000 and 2018) to fix that variable and continue to use 1.5% of value as the tax rate (alternative assumptions and outcomes are presented in Table 4). When combined with the $60 low price and the $100 high price, the 5% investment return yields a 2050 ending balance range of [$3.16B, $5.27B]. For the 10% investment return, the range increases to [$8.71B, $14.5B]. While difficult to predict, it would not be too surprising to have an ending balance between the combination of these two ranges [$3.16B, $14.5B]. Using the results from our regression analysis to decrease annual production by 4.14%, due to the increased TPT rate, has a relatively small effect on the forward-looking estimates; doing so decreases the 2050 end balances by 4.14%. For example, the 5% investment return range decreases to [$3.03B, $5.06B] or about 16–26% of 2014 state general fund expenditures, while the 10% return range falls to [$8.34B, $13.9B] or about 43–72% of 2014 state general fund expenditures.

One key question is whether the mining companies would continue to produce if a 1.5% of value tax was added to the TPT rate: could the additional 1.5% tax be sufficiently large to increase the likelihood of future shut-downs or exits? Although our regression results suggest that production is not particularly sensitive to price, as noted, shut-downs have occurred. One possibility would be to create an inflation adjusted price threshold that would have to be exceeded for the tax to be imposed. The goal would be to set the threshold price close to but sufficiently above a shut-down price (due to the tax) such that firms would be expected to fully produce when the threshold was met or exceeded. If price was between the threshold price and shut-down price, the additional tax would not be imposed in hopes of avoiding a shut-down created by the additional tax. The choice of price would be open for debate; our regression results suggest that, for US producers, quantity supplied may be more responsive to variables that incorporate steel costs (or price) as an indication of iron ore value rather than iron ore prices. The price threshold would complicate the SWF funding mechanism and may lead to no additional revenue from some production units in some years but may be a way forward in the likely outcome of industry concerns over an additional tax amount.

Copper-nickel

Olson (1967) noted the potential for copper-nickel mining in his report The Mining Industry of Minnesota: "Stimulated by high demand, extensive exploration activities for copper-nickel were conducted along the Duluth Gabbro in Cook, Lake, and St. Louis Counties."(p.423). Over fifty years later, there are two proposed sites that have released technical reports. While the sites are not fully approved, and controversial, they could provide another source of revenue for an SWF. We are not endorsing approval of these mine sites, rather we

Table 4 Taconite forward-looking results—sensitivity analysis

Added value tax%	2018 price	Inflation rate	2050 price	Annual investment return	2050 SWF value ($B USD)	2050 value with production adjustment
1.5%	$60	2%	$113	5%	$3.16	$3.03
	$60	2%	$113	10%	$8.71	$8.34
	$60	4%	$210	5%	$4.06	$3.89
	$60	4%	$210	10%	$10.4	$10.0
	$100	2%	$188	5%	$5.27	$5.06
	$100	2%	$188	10%	$14.5	$13.9
	$100	4%	$351	5%	$6.76	$6.48
	$100	4%	$351	10%	$17.4	$16.7
1.0%	$60	2%	$113	5%	$2.11	
	$60	2%	$113	10%	$5.80	
	$60	4%	$210	5%	$2.70	
	$60	4%	$210	10%	$6.95	
	$100	2%	$188	5%	$3.52	
	$100	2%	$188	10%	$9.67	
	$100	4%	$351	5%	$4.51	
	$100	4%	$351	10%	$11.6	
2.0%	$60	2%	$113	5%	$4.22	
	$60	2%	$113	10%	$11.6	
	$60	4%	$210	5%	$5.41	
	$60	4%	$210	10%	$13.9	
	$100	2%	$188	5%	$7.03	
	$100	2%	$188	10%	$19.3	
	$100	4%	$351	5%	$9.01	
	$100	4%	$351	10%	$23.2	

acknowledge their potential and considering whether they could significantly impact the value of an SWF.

In March 2018, an updated NI 43-101 Technical Report was released for the NorthMet project. The report includes the metals expected to be recovered and some pricing analysis; copper, nickel, and palladium are expected to generate over 90% of net revenue. Since each of the seven metals mined is subject to significant price fluctuations, we use a straightforward method to calculate potential scenarios. The report includes expected gross revenues by year over the 20 year life of the project (Black et al. 2018).

To align with the analysis above (taxing of extraction), this scenario deposits 1.5% of annual gross revenues into the SWF.[14] The amounts generated are relatively small; direct contributions through 2040 summed to $103 million, a 5% investment return scenario generated a 2040 ending balance of about $174 million, and a 10% investment return scenario generated about $307 million. Recent reports have suggested that the company (PolyMet) may be interested in a significant expansion, although PolyMet itself denies it. The possibility of larger or more mines, however, might be taken into account when deciding whether to create an SWF (Marcotty 2013).

In October 2014, a NI 43-101 Technical Report on Prefeasibility Study was released for the Twin Metals Minnesota Project (Barber et al. 2014). The report includes a table (Table 22-4) that has projected total revenues for project years 2021–2050. This scenario deposited 1.5% of annual total revenues into the SWF. The amounts generated are significantly larger than for the NorthMet project; direct contributions through 2050 summed to $460 million, a 5% investment return scenario generated a 2050 ending balance of about $1.1 billion, and a 10% investment return scenario generated about $2.8 billion.

In total, the two proposed copper-nickel mines could make meaningful contributions to an SWF. Adding 1.5% of the revenues from each project each year lead to the following results in 2050; direct contributions through 2050 summed to $563 million, a 5% investment return scenario generated a 2050 ending balance of about $1.4 billion, and a 10% investment return scenario generated about $3.6 billion.

[14] The contribution magnitudes from copper-nickel mining are relatively small, less than one fourth of taconite, and are generated from multiple minerals; therefore, production effects were not estimated.

Conclusion

Based on our analysis herein, Minnesota still has enough minerals to create a substantial permanent fund. After accounting for an estimated 4% production loss from an increased tax rate and using reasonable assumptions of a 2% inflation rate and a 5% annual investment return, the fund size could range between \$3 billion and \$5 billion by 2050 depending on price (about 16–27% of 2014 state general fund expenditures). Expansion of the tax base beyond iron ore has the potential to include two potential copper-nickel projects, which would further increase the size of Minnesota's potential SWF.

If Minnesota chose to start distributing returns on the fund in 2050, a 5% rate would yield about \$150–\$250 million per year. How could that amount be used and would the social benefits likely exceed the opportunity costs of the rents going into the private sector? One possibility would be to use the rents to invest in the knowledge economy by focusing on human capital development. The returns could be invested, for instance to make progress on the well- documented educational attainment gaps that continue to challenge the state (see e.g., Shockman 2019). Rolnick and Grunewald (2003) outline an inflation adjusted \$270 million (\$2020) annual program for early childhood development for 20,000 children in Minnesota. Based on a pilot study to estimate the returns on investment, they find an \$8.74 return per dollar invested in education. Further, nearly 82% of this return accrued to the public through decreased crime and other public goods. Extending their analysis, the authors find an estimated real internal rate of return of 16%—which is substantial and in contrast to private rents, the significant public portion of these benefits would flow to all Minnesotans.

Given the money would not be available until 2050, we appreciate that we do not know the exact situation regarding early childhood development at that time. But, note that a recent non-profit organization, Close Gaps By Five, estimates that the number of children at risk of falling into achievement gaps in Minnesota is about 35,000 (Close Gaps By Five 2021). High-quality programs focusing on human capital development are likely to provide the best returns (Phaneuf 2019). Additionally, it has been suggested that more program evaluation is needed (Phaneuf 2019). Another possibility would be to extend the program to offer scholarships for post-secondary education (somewhat similar to the SWF-based Hathaway Scholarship in Wyoming only more targeted). Therefore, whether the \$150–\$250 million was used to expand the number of children eligible for early childhood development, increase the quality of programs or evaluation, or expand programs, the SWF returns could help address a key social challenge in the state and generate large public returns.

If Minnesota residents were more patient, the fund could be allowed to grow without withdrawals for a longer period. The \$3–\$5 billion fund, with 5% annual returns, would grow to \$34–\$57 billion by 2100. With 10% returns, the SWF could reach \$352–587 billion by 2100. An SWF of these sizes would open a wider range of internal uses and external investments for the SWF returns.

Given the estimated magnitude of the SWF principal, the amount of the possible annual investment rents that could be generated, and the possibility of high public returns from those rents, our analysis suggests it is not too late to start a fund in Minnesota. However, policymakers must considered the issue urgent, as two factors act to increase the opportunity costs of delaying the implementation of such a fund. The first is related to the declining supply of reserves. As mining continues, the current stock of reserves is reduced. Furthermore, as mentioned previously, two of Minnesota's mines are currently scheduled to cease production prior to 2050. The second factor is a core tenant of finance. Investing early brings greater potential for growth, and greater potential benefits from compounding.

Adding political realities back into the picture, we recognize that starting an extraction-based SWF now in Minnesota is not straightforward for three reasons.[15] First, since the taconite production tax is paid in lieu of local property tax, it is unlikely that a significant portion could be used to generate revenue for an SWF. This implies that Minnesota would need to significantly increase the TPT rate or impose a new state tax on minerals. The mining industry would likely oppose such a tax, especially given the difficult history of shut-downs in taconite production. Perhaps, a rule could be imposed such that the tax would only be collected when price exceeded a threshold. Second, another unknown is whether the proposed copper-nickel projects will begin operation in the near future. While not endorsing approval of these mine sites, we acknowledge their existence would likely have a significant impact on the magnitude of an SWF. Third, while the possibility remains that new mining projects could be proposed, we know of none on the immediate horizon.

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[15] In 2017, mining and natural resources make up approximately 3 percent of the Minnesota's state GDP. In contrast, in Northern Minnesota where the mines are located, mining and natural resources is 13 percent of GDP (as reflected by the Duluth metro area).

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