DEPARTMENT OF ECONOMICS
OxCarre
Oxford Centre for the Analysis of Resource Rich Economies

Manor Road Building, Manor Road, Oxford OX1 3UQ
Tel: +44(0)1865 281281 Fax: +44(0)1865 271094
oxcarre@economics.ox.ac.uk www.oxcarre.ox.ac.uk

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Digging Deep for the Heritage Fund: Why the right fund for Alberta pays dividends long after oil is gone

Ton van den Bremer

(University of Oxford)

&

Frederick van der Ploeg
(OxCarre)

Direct tel: +44(0) 1865 281281 E-mail: oxcarre@economics.ox.ac.uk

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DIGGING DEEP FOR THE HERITAGE FUND: WHY THE RIGHT FUND FOR ALBERTA PAYS DIVIDENDS LONG AFTER OIL IS GONE†

Ton van den Bremer and Rick van der Ploeg

SUMMARY

Albertans have long been aware that while their provincial government has shown a lack of consistent discipline in investing oil royalty revenues in the Alberta Heritage Savings Trust Fund, the Norwegians have been showing oil-rich jurisdictions just how effectively saving can be done. While Alberta's fund was established in the mid-1970s, more than a decade before Norway began its national savings program, the Norwegian fund was worth more than $900 billion as of the beginning of 2014; Alberta's is worth roughly $15 billion today, revealing the province's inability to stick with firm, routine contribution commitments, and its occasional habit of using the fund's earnings to cover spending priorities. But while many economists, politicians and pundits from both the left and right have long pointed to Norway as the model for Alberta to follow, it would in fact be wrong for Alberta to mimic Norway's strategy. Indeed, the right plan for Alberta can set the province up in better shape for the future than even Norway will be.

The Norway approach will inevitably prove unsustainable. As it is, Norway deposits all resource revenue into its fund, which then distributes a dividend to the government every year worth four per cent of the fund's wealth. As the fund grows, so to does the size of the dividend. Yet, as wealth is converted from belowground assets (oil) to aboveground assets (cash and investments), the belowground wealth becomes gradually but inevitably depleted. At some point, all of Norway's oil wealth will have been converted into aboveground assets, and the dividend will eventually have to be adjusted downward.

A more sustainable approach, and one that Alberta should pursue, is one where the dividend is a falling proportion of fund assets. In other words, the province will want to calculate an appropriate dividend that is a fraction not just of the size of the financial fund (aboveground), but a constant fraction of total wealth — the value of the belowground assets and the aboveground asset portfolio. This ensures that the dividend grows in line with GDP.

What is feasible for Alberta is an ongoing resource dividend equivalent to 30 per cent of government revenue. In order to achieve that goal, the province will have to build the fund such that it is worth the equivalent of 40 per cent of provincial GDP by 2030, 100 per cent of GDP by 2050, and 165 per cent of GDP in the year 2100. This means that within just the next 16 years, the Heritage Fund will need to be worth $200 billion in order to achieve its first benchmark — more than thirteen times its current size. Note the differences here with the recommendations made by the Alberta Financial Investment and Planning Advisory Commission (the Mintz commission), which advocated saving a fixed percentage of Alberta's resource revenue each year, and set a 2030 target at just half that size.

But what this plan does have in common with the Mintz commission's recommendations is that it requires the Alberta government to finally become serious about preparing itself to preserve wealth for future generations through the use of disciplined and meaningful investment in the resource fund. A serious investment approach also must mean that the fund should not be used as a source of capital investment to favour businesses in the province; Albertans have perfectly good access to capital markets, and worthwhile investments can and should compete for capital funds on their merits, not their location. Quite the contrary, a properly diversified Heritage Fund should be investing largely, if not entirely, outside the province. Most importantly, of course, is that Albertans need to insist that their government commit to a strategic plan for investing its oil revenue. Alberta can create a better fund strategy than Norway's for ensuring economic sustainability through future generations, but first it must finally get serious about doing it.

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1. INTRODUCTION

The mission of the Alberta Heritage Savings Trust Fund is "to provide prudent stewardship of the savings from Alberta's non-renewable resources by providing the greatest financial returns on those savings for the current and future generations of Albertans." The investment approach is focused on the long term, global in outlook, diversified and professionally managed. The fund was created in 1976 and 30 per cent of government resource revenue was initially transferred to the fund. With the economic crises of the early 1980s, this percentage was halved and eventually cut to zero in 1987. After the Alberta government had eliminated its accumulated debt in 2005 and started showing budget surpluses, revenue was again transferred to the fund. Since its inception, $33 billion has been withdrawn from the Alberta Heritage Fund to support spending in areas such as health care, education, infrastructure, debt reduction and social programs. The value of the Alberta Heritage Savings Trust Fund stood at $15.1 billion, or 4.7 per cent of Alberta's GDP, as of March 2014 (it was $14.9 billion or 4.8 per cent of GDP as of March 2013).[1] In addition to the Alberta Heritage Savings Trust Fund, a second, much smaller fund, currently known as the Contingency Account, with a value of $4.7 billion, or 1.5 per cent of Alberta's GDP as of March 2014 ($2.7 billion or 0.9 per cent of GDP as of March 2013) is used to smooth revenue shocks arising from volatilities in oil and gas prices.[2] We see these two types of funds as examples of what we will call, respectively, an intergenerational fund and a liquidity fund, and we will call the total of these two funds simply "the fund."[3] We do not only consider bitumen as the dominant source of resource revenue for Alberta, but also revenue from the sale of crude oil and natural gas.

With natural resource revenues remaining high for years to come, the time is ripe to take a more structural approach to managing Alberta's fund. For this purpose we first argue that it is indeed useful to distinguish between an intergenerational fund to distribute the temporary proceeds from natural resource wealth over many generations, and a liquidity fund or precautionary savings fund to cushion the adverse impact on government income of a drop in the world price of oil. Resource-rich countries are increasingly turning to sovereign wealth funds to manage their natural resource wealth. Our previous research has calculated what the optimal sizes of these two funds should be for Norway, Iraq and Ghana.[4] Optimal policy is very different for different countries. Since Iraq's windfall is much longer lasting than those of Norway or Ghana, it requires a relatively small intergenerational fund but a relatively large liquidity fund. Since Ghana suffers from capital scarcity, it can use some of the windfall to invest in the domestic economy, but it will be limited in doing so by absorption constraints.

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[1] We use the book values reported in the annual budget documents by Alberta Finance. Using the slightly higher current fair market value would only marginally affect our calculations and leave our qualitative policy recommendations unaltered.

[2] Given the objective of fiscal stabilization, the contingency account is much more invested in short-term, fixed-income securities than is the Heritage Savings Fund.

[3] Both figures come from Alberta's 2013 provincial budget (http://finance.alberta.ca/publications/budget/budget2013/fiscal-plan-savings-plan.pdf). The Alberta Government has a number of smaller funds, which include the Medical Research Endowment Fund, the Science and Engineering Endowment Fund and the Scholarship Fund. Their total value is $3.4 billion or 1.1 per cent of Alberta's GDP as of March 2014 ($3.5 billion or 1.1 per cent of Alberta's GDP as of March 2013). We do not include these smaller funds as part of our initial fund size, since they are domestic investment funds. The merit of these funds should be decided on the basis of their social returns. If these are satisfactory, Alberta can make use of international capital markets to finance these and not the Heritage Fund.

[4] T.S. van den Bremer and F. van der Ploeg, "Managing and Harnessing Volatile Oil Windfalls," *IMF Economic Review* 61, 1 (2013): 130-167.

Our objective here is to give estimates for the optimal sizes of the intergenerational and liquidity funds for Alberta, and to exposit our methodology and policy recommendations for Alberta. Our policy recommendations are based on two modifications of the well-known permanent-income hypothesis: first, we take account of both belowground resource wealth and aboveground financial wealth and recommend that the amount taken from the fund for general budget purposes — the so-called resource dividend — is not a fixed percentage of financial wealth but of total wealth; second, we take account of the need for precautionary saving to cope with the volatility of oil and gas prices.

Our recommendations are thus very different from the so-called Norwegian bird-in-hand rule, which states that all resource revenue should be deposited in the fund and that the annual resource dividend should be four per cent of the financial wealth that has accumulated in the fund. As the fund grows, the amount withdrawn from the fund thus increases. This violates the core insight of the permanent-income hypothesis, which states that spending should react to permanent, not present income. The bird-in-hand rule is, in fact, unsustainable, and the resource-dividend percentage will eventually have to be adjusted downwards over the years as belowground resource wealth is depleted. This is why we argue that the resource dividend should be a constant percentage (albeit smaller than four per cent) of the sum of fund wealth and natural resource wealth. In the long run, this is a more credible and sustainable policy than Norway's four per cent rule.

We use historical data and official projections to calculate estimates of the size and development of the intergenerational and liquidity funds for Alberta's revenue from bitumen, crude oil and natural gas and the corresponding optimal withdrawal from the funds for the general budget, which we refer to as the resource dividend. How much of the resource dividend is allocated to public spending, tax cuts or dividends based on purely demographic principles (demogrants) depends, of course, on political preferences.[5] In its 2007 review of Alberta's saving policy, the Alberta Financial Investment and Planning Advisory Commission (the Mintz commission) recommended setting a target of achieving $100 billion in net financial assets by 2030 and saving a fixed percentage of Alberta's total revenues each year as part of the budget.[6] Once this target is achieved, the commission foresees a permanent annual income of $4.5 billion to fund public services and/or maintain low taxes in the future. It is now 2014 and it is evident that these recommendations have not been taken to heart. As mentioned above, we take a different approach based on the permanent-income hypothesis and recommend a fixed percentage of the permanent value of the sum of belowground resource wealth and aboveground financial assets (the fund) be saved annually. Our target for accumulated financial assets by 2030 is double that of the Mintz commission's in 2007, namely $200 billion.

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5 If it is desirable to have a stronger supply-side of the economy, one may use a bigger part of the resource dividends for investment, infrastructure and tax cuts. In fact, the Alberta Financial Investment and Planning Advisory Commission (the Mintz commission) dismissed Alaska-style dividend payments, as they are lump-sum in nature and have little benefit for the economy.

6 Alberta Financial Investment and Planning Advisory Commission, *Preserving Prosperity — Challenging Alberta to Save* (Report and Recommendations, 2007), http://www.finance.alberta.ca/publications/other/2008-0131-fipac-final-report.pdf.

Although we focus on oil- and gas-price volatility and to some degree asset-price volatility, we must at the outset make the proviso that the long-term risk for Alberta is as much based on future, and hence unknown changes in technologies, resource discoveries, uncertainties about transportation investments such the Keystone Pipeline System, which is still awaiting final approval for expansion, and uncertainties about future carbon-emission constraints and other policies that will impact Alberta's ability to maintain or expand resource production. These formidable uncertainties are as much a driver of precautionary policies as the driver based on depleting and investing Alberta's non-renewable resources in the face of oil-, gas- and asset-price volatility. Our estimates of optimal precautionary saving thus provide a lower bound.

There is one further controversial implication of our policy framework. This is that there is no need to have, next to an intergenerational fund and a liquidity fund, a separate investment fund that is financed by resource revenue and used to finance domestic public or public-private investment projects. Similarly, there is no need for the intergenerational or liquidity funds to invest in the Alberta economy (either public capital or private capital). If an investment in the domestic economy is worthwhile and has a return at least equal to the market rate of interest, it can be funded by borrowing on world capital markets. Alberta should thus not invest in the domestic economy just because it has resource revenue or funds. Such investment projects should be decided on their own merits and one should avoid political favoritism, rent seeking and tying the hands of future generations who might have different priorities. In fact, resource revenue should, as in Norway, be mainly invested outside the province. The appropriate vehicles for this are an intergenerational fund and a liquidity fund. The thrust of the most recent provincial budget is, however, to use the savings funds to invest in the province, which is in line with the priorities of politicians and commentators of all political persuasions.[7]

This paper is laid out as follows. The key economic principles of optimal exhaustible resource management are outlined in section 2. Our estimates of the optimal size of the intergenerational and the liquidity fund are presented and discussed in section 3. This is followed by recommendations on fund management in section 4. Conclusions are drawn in section 5.

2. HOW BEST TO MANAGE VOLATILE RESOURCE REVENUE STREAMS

The revenue stream from fossil fuel extraction that accrues to the Alberta government has two key features: it is temporary, as the revenues end when the resources have been fully depleted or have become too costly to deplete; and it is volatile, as the prices of oil and natural gas sold on world markets are highly volatile. These provide rationales for an *intergenerational* fund to smooth consumption per capita across generations and a *liquidity* fund to cushion the impact of volatility of the world oil price. There is no role for an *investment* fund to make capital

[7] Many developing oil-rich economies suffer from capital scarcity, which means that they have to pay an interest premium. In that case, investment will be too low and a resource bonanza can alleviate the capital scarcity constraints and thus lead to more investment (e.g., F. van der Ploeg and A.J. Venables, "Natural Resource Wealth: The Challenge of Managing a Windfall," *Annual Review of Economics* 2 (2012): 315-337). Part of the oil windfall can thus be used to boost investment and an investment fund is warranted. However, this is not the case for Alberta, which has good access to international capital markets.

investments in the province because the government, private individuals, and firms in Alberta have access to international capital markets. Thus, there is thus no reason to spend a part of the resource revenues to promote public or private investment in Alberta. The assets of the intergenerational funds and the liquidity fund, which we will simply refer to as the "fund," and denote by F, should be held in the form of financial and other assets. The composition of the portfolio of assets will be discussed in section 4.

We begin by describing the rules that would govern the intergenerational fund and then we consider the role of oil price volatility in determining the size of a liquidity fund.

2.1. How to build an intergenerational fund

To understand the rationale for an intergenerational fund, we first abstract from oil price volatility and see how best to manage expected future resource revenue streams over time. The basic idea is that a society's wealth, W, consists of its aboveground financial assets, F, and the value of its belowground resource assets, V. When the oil and gas resources are extracted from the ground, they must be fully converted into aboveground assets so that total wealth is unchanged. With a properly managed fund, there is a resource dividend, denoted by D, that is provided to the government each year to fund public services so that every generation can benefit from the oil-wealth legacy. One appealing rule for the resource dividend is that it should be a constant proportion of each generation's total wealth. In Appendix A we describe the underlying economic model for this rule for the resource dividend and here we only summarize the key features of the fund that result:

(i) The resource dividend that is available to fund government services is a constant proportion of total aboveground and belowground wealth.

(ii) The decline in belowground wealth is exactly compensated by an increase in aboveground wealth held in financial assets in the fund so that the total of wealth, both aboveground and belowground, remains a constant fraction of total GDP.

(iii) The resource dividend grows at the rate of GDP growth even if resource revenues decline over time, and it remains a constant proportion of each generation's non-resource income. This implies that each generation can receive the same ratio of public services to total non-resource income by imposing the same overall tax rate.

(iv) The faster the rate of depletion of non-renewable resources and the faster the decline in resource revenues, the larger the proportion of its resource revenue that is saved in the intergenerational fund.

(v) The savings rate out of resource revenues is not constant over time.

We can illustrate these ideas using a relatively simple spreadsheet example presented in Table 1 in which resource revenue is 0.1 units in Year Zero, $R_0 = 0.1$, and declines at a rate of 3.0 per cent per year, $\omega = 0.030$. The initial value of the fund is assumed to be zero, $F_0 = 0$. The initial population after normalization is set equal to one, as is the initial per capita income, so that total non-resource GDP is equal to one in the initial year and resource revenues are 10 per cent of non-resource GDP. The annual population growth rate is 1.3 per cent, $n = 0.013$, the annual productivity growth rate is two per cent, $g = 0.020$, and the annual return on funds invested in the fund is 6.1 per cent, $r = 0.061$. In this simple example we ignore extraction costs and set the oil-price trend growth to zero.

The initial value of the stock of resources in the ground equals the present value of the stream of declining natural resource revenues, i.e., $V_0 = R_0/(r+\omega) = 0.1/(0.061+0.03) = 1.099$. This value is thus lower if the return on investments in the fund r is higher and revenues decline at a faster rate ω. The resource dividend, D_0, in Year Zero grows at the trend growth rate of the economy, $n + g = 3.2$ per cent per year, so that the dividend per capita grows at the productivity growth of the economy. This corresponds to 30.8 per cent of resource revenue R_0.[8]

TABLE 1: EXAMPLE OF AN INTERGENERATIONAL RESOURCE REVENUE FUND

Year	Resource Revenue R	GDP	Resource Dividend D	Saving out of Resource Revenue S = R–D	Savings Rate out of Resource Revenues S/R	Value of the Fund F	Value of the Resource Belowground V
0	0.100	1.000	0.031	0.069	0.692	0.000	1.099
1	0.097	1.034	0.032	0.065	0.672	0.069	1.066
2	0.094	1.068	0.033	0.061	0.651	0.139	1.035
3	0.091	1.104	0.034	0.057	0.628	0.209	1.004
4	0.089	1.141	0.035	0.054	0.604	0.279	0.975
5	0.086	1.179	0.036	0.050	0.578	0.350	0.946
10	0.074	1.391	0.043	0.031	0.422	0.714	0.814
20	0.055	1.935	0.060	-0.005	-0.085	1.523	0.603
50	0.022	5.207	0.160	-0.138	-6.180	5.477	0.245
75	0.011	11.882	0.366	-0.355	-33.686	12.941	0.116
100	0.005	27.113	0.834	-0.829	-166.561	29.739	0.055

Note: The ratio of the resource dividend to GDP and the ratio of total wealth to GDP is constant for all time periods, i.e., $D_t/GDP_t = 0.031$ and $(F_t+V_t)/GDP_t = 1.099$ for all $t \geq 0$. The growth rate of GDP, population growth, the interest rate and the decline of resource revenue are, respectively, 3.3 per cent, 1.3 per cent, 6.1 per cent and three per cent per annum. The resource dividend is a constant 2.8 per cent of total wealth.

Hence, 3.08 per cent of initial non-resource income is what the government can use to fund public services or provide income transfers to the population. Savings out of resource revenue in the initial year is thus 0.1 - 0.0308 = 0.0692, which is deposited in the fund and therefore the value of the fund in Year One is 0.0692. As revenues will have dropped by three per cent after a year, the value of the resources in the ground after one year will drop to 1.0664. GDP grows at the rate of population and productivity growth, 3.3 per cent, so that GDP after one year is 1.033. Note that total wealth as a proportion of GDP after one year equals (0.0692 + 1.0664)/1.033 = 1.099. Thus the proportion of total wealth to GDP does not change from year to year.

The resource dividend grows at the same rate as GDP and total wealth, i.e., 3.3 per cent per annum. The resource dividend is the same fraction of total wealth in each year. This fraction is the growth-corrected real return on assets.[9] Total savings out of resource revenues in Year One

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[8] It corresponds to $(r - n - g)\ V_0/R_0 = (0.061 - 0.013 - 0.02)/(0.061 + 0.03) = 0.308$. The value of resources in the ground in Year One decreases to $V_1 = 0.1 \times \exp(-0.030)/(0.061+0.030) = 1.0664$.

[9] The resource dividend after one year is, $1.033 \times 0.0308 = 0.0318$. The dividend in years One and Two are the same, since $0.0308/1.099 = 0.0318/(0.0692+1.0664) = r - g - n = 0.028$.

is $S_1 = R_1 - D_1 = 0.0970 - 0.0318 = 0.0652$, and the fund in Year Two will thus be $F_2 = (1 + r) F_0 + S_1 = (1 + 0.061) \times 0.0693 + 0.0652 = 0.1387$. Table 1 shows a continuous-time version of this model (see Appendix A for details) for the first five years, and then the values of the variables after 10, 20, 50, 75 and 100 years. The key design feature of the resource savings fund is that total above- and below-ground wealth, $F + V$, would remain a constant fraction of GDP equal to 1.099. The resource dividend is then also a constant fraction of GDP equal to 0.031. However, the savings rate out of resource revenues, S/R, declines from 0.692 in the initial year and becomes negative after 18 years. Hence, the resource dividend exceeds the resource revenue after 18 years. Over time, as the value of the remaining resource in the ground goes to zero, the ratio of the value of the fund to GDP approaches 1.099 or approximately 110 per cent of GDP.

2.2. Oil price volatility and the case for a liquidity fund[10]

Prudent policy-making is built on a greater desire to avoid negative outcomes than one to seek positive outcomes. In the model of optimal saving in the face of volatile oil prices, this is captured by a coefficient of relative prudence *CRP*. Policy-makers face uncertainty about future oil prices, oil, gas and bitumen reserves, asset returns and general economic outcomes, notably growth prospects. We focus on the most important form of uncertainty for Alberta, namely oil price volatility. In the face of this uncertainty, it is optimal to accumulate precautionary buffers, which act as insurance against future drops in oil prices. The extent of this precautionary saving and the resulting magnitude of the precautionary buffers that are being accumulated are larger if the coefficient of relative prudence and relative volatility of commodity prices are substantial. Furthermore, the expected growth in consumption and the resulting degree of precautionary saving are higher if oil price shocks are less transient, as a greater part of the revenue resulting from shocks is saved if these shocks are more permanent. Two extreme cases can be considered. If shocks are permanent and all future prices change by the same amount as the initial shock, the required precautionary buffers will be large. If shocks are purely transient and they do not have an effect on future expected oil prices, then no precautionary saving are necessary. In general, with mean reversion in the price shocks, such that a one-dollar increase in the current oil price on the expected values of future price shocks is positive but less than one, the required precautionary saving is smaller. Finally, there is less need for precautionary saving if productivity growth makes the province richer in the future and hence better able to deal with future income shocks.

To summarize, in addition to an intergenerational sovereign wealth fund, Alberta should also have a liquidity fund to insure against oil price volatility. This liquidity fund has to be larger if oil prices become more volatile and oil price shocks become more persistent, growth prospects worsen, and policy-makers become more prudent. To the extent that policy-makers dislike current generations making consumption sacrifices for future generations (technically speaking to the extent that they have more intergenerational inequality aversion), there is less precautionary saving, and a lower liquidity fund. Although a temporary resource-revenue windfall requires a large intergenerational fund — the revenues are high for only a few years — only a small liquidity fund is required, and the effect of oil price volatility on the precautionary buffer only occurs during the short period of the windfall.

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[10] Technical details of how to derive precautionary saving rules are given in Appendix B.

3. ESTIMATES OF OPTIMAL INTERGENERATIONAL AND LIQUIDITY FUNDS FOR ALBERTA[11]

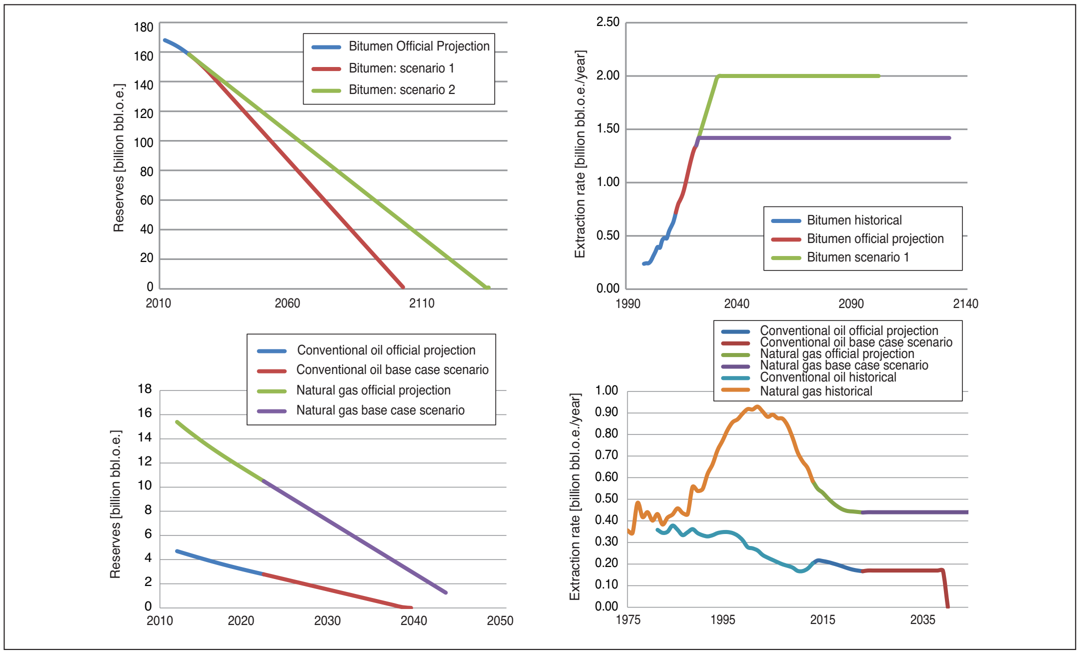
To estimate the optimal sizes of the intergenerational and liquidity funds and the resulting resource dividends that these can support for Alberta, we distinguish resource rents from bitumen, conventional crude oil and natural gas. We also distinguish two scenarios for the resource-extraction paths.

3.1. Background data and assumptions

3.1.1. EXTRACTION RATES AND RESERVE ESTIMATES

For the extraction rates of bitumen, conventional crude oil, and natural gas, we use official projections available until 2021. In these official projections production of bitumen rises from 0.72 to 1.4 billion barrels per year during the period 2012–2021. Production of conventional oil and natural gas are set to decline from 0.20 and 0.58 to 0.17 and 0.44 barrels of oil equivalent,[12] respectively, over the same period. We allow for some new discoveries (but do not consider the effect of discovery shocks) and estimate initial reserves to be 168 billion barrels of bitumen, 4.7 billion barrels of conventional oil and 15.4 billion barrels of oil equivalent of natural gas (see B.2 and B.3 in Appendix B). Based on these reserves, we consider two scenarios for the period after 2021. They are shown in Figure 1.

FIGURE 1: PROJECTIONS FOR EXTRACTION RATES AND RESERVES AND HISTORICAL DATA



[11] Calibration details are given in Appendix C.

[12] To facilitate swift comparison, reserves and production rates of natural gas are shown in barrels of oil equivalent (b.o.e.), where we use the following definition: 1,000 bbl of natural gas corresponds to 1.000 bbl of oil equivalent (Norwegian Petroleum Directorate, "Facts: The Norwegian Petroleum Sector" (Oslo: Ministry of Petroleum and Energy, 2011), http://www.npd.no/ en/Publications/Facts/Facts-2011), which corresponds approximately to equivalent energy content. We note that under this definition, the per b.o.e. price of natural gas is significantly lower than the price of oil per barrel, reflecting imperfect substitution and to, a lesser extent, transportation costs.

In scenario 1 (benchmark) we let the extraction of bitumen increase further at the same 2.0 billion barrels per year from 2030 onwards until exhaustion in 2100. Production of conventional oil and natural gas continue at their respective 2021 rates of 0.16 and 0.44 billion barrels of oil equivalent until their respective exhaustion in 2038 and 2044. To examine the sensitivity to changes to the extraction rate, we consider a second scenario (scenario 2), in which the extraction rate of bitumen stays constant after 2021 at a rate of 1.4 billion barrels per year. The extraction rates for conventional oil and natural gas are left unchanged.

3.1.2. GOVERNMENT RESOURCE RENTS

To convert extraction rates into a dollar value, we first calculate resource rents consisting of revenue from selling the resource minus extraction costs. We use extraction costs of $15 per barrel of oil equivalent for both conventional oil and natural gas. To reflect the large costs associated with bitumen production, we use an extraction cost of $32 per barrel (see B.4 in Appendix B). We assume conventional oil is sold at the WTI price and natural gas at the Henry Hub NYMEX natural gas price, but use the much lower (also below Western Canadian Select) average field gate price as an estimate of the actual price of a barrel of bitumen (see B.5 in Appendix B).

For all three resource prices, we adopt autoregressive (AR(1)) price processes, reflecting the significant reversion to the mean observed in resource prices. We rely on the calibration in van den Bremer and van der Ploeg[13] for the conventional oil and natural gas price and use a mean price of $110 per barrel, a mean reversion of six per cent per year, and a volatility of 26 per cent for conventional oil. For natural gas, we take a mean price of $32 per barrel of oil equivalent, a mean reversion of six per cent per year, and a volatility of 20 per cent. For bitumen, we adopt the same mean reversion and volatility, but a substantially lower mean price of $80 per barrel. We assume these prices are perfectly correlated. Initial prices on Jan. 1, 2013 are $96 per barrel natural of oil, $64 per barrel of bitumen and $11 per barrel of oil equivalent of natural gas (all prices in Canadian dollars). Extraction of natural gas will initially not be profitable, but will eventually become profitable as a result of price reverting back to the mean. Extraction costs may even exceed prices for natural gas, in which case we set gas rents to zero.

In our calculations of the optimal Albertan intergenerational and liquidity funds and the accompanying resource dividends, we assume that the share of resource rent that accrues to the government remains at 34 per cent and the share of government in the economy remains at 14 per cent (both represent the 2002–2012 average, see C.7 in Appendix C). We focus on outcomes for the Alberta government.

3.1.3. RETURN ON THE FUND AND GENERAL ECONOMIC TRENDS

The initial size of the fund is $17.6 billion (consisting of both the Contingency Account and the Heritage Savings Trust Fund in March 2013) and corresponds to a little less than six per cent of total GDP. We set the real return on the fund to r = 6.1 per cent per year, which corresponds to the annual real return on the Alberta Heritage Savings Trust Fund from 2002 to 2012 (see B.1 in Appendix B). Section 3.5 discusses robustness check outcomes for a lower

[13] van den Bremer and van der Ploeg, “Managing and.”

real return on 4.5 per cent per year. Trend population growth n is set at 1.3 per cent per year, which is the long-term projected growth rate for 2014–41.[14] The trend productivity growth rate g is set at 2.0 per cent per year, so that the trend growth of non-resource GDP is taken to be 3.3 per cent per year. We take an elasticity of intertemporal substitution of 0.5 and thus set the social rate of discount to $\varrho = r - g/0.5 = 2.1$ per cent per year. This implies that spending in efficiency units or as a percentage of non-resource GDP is smoothed, so that the resource dividend (the annuity) per capita grows at the rate of productivity growth g. The resource dividend thus grows in line with wages and profits.

3.2. Benchmark estimates and the effects of prudence

Figure 2 reports the optimal resource dividend under various scenarios for the general budget in response to resource income in Alberta, and the corresponding optimal size of the savings fund for extraction scenario 1 for various degrees of prudence. The red line in the first panel of Figure 2 corresponds to the optimal spending/saving mix to build up an intergenerational fund. The red line in the second panel of Figure 2 shows the corresponding optimal size of the intergenerational fund if there is no volatility (or if policy-makers are not prudent). The intergenerational fund grows gradually from 5.7 per cent of GDP in 2013 to 159 per cent in 2100. This will sustain an annual resource dividend equal to approximately 25 to 30 per cent of government revenue.[15]

The purple and blue lines in Figure 2 correspond to a moderate (benchmark) and high degree of relative prudence. The optimal initial resource dividend drops from 28 per cent (*CRP* = 0) to 26 per cent and 21 per cent for degrees of relative prudence of three and 10, respectively. The additional initial precautionary saving leads to the buildup of a larger fund with a final fund size in 2010 of 6.5 per cent, or 21 per cent points larger, for degrees of relative prudence of three and 10, respectively.

For the benchmark relative prudence of three, the liquidity fund is thus relatively small compared with the intergenerational fund: it grows gradually from zero in 2013 to a mere 6.5 per cent of GDP in 2100. However, with a much larger relative prudence of 10, the light blue lines indicate that the accumulated liquidity fund is much larger. This implies that the initial resource dividend will have to be smaller, but that in the long run, larger resource dividends can be expected.

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[14] The figure is from Alberta Finance, *Population Projection: Alberta 2014-2041* (2014), http://finance.alberta.ca/aboutalberta/population-projections/2014-2041-alberta-population-projections.pdf. In the past, Alberta has seen relatively high rates of population growth with a 10-year average of 2.2 per cent growth and 20-year average of 2.0 per cent growth (Statistics Canada, 2013).

[15] It is thus fairly constant. Variations merely reflect normalization by total GDP, which does not grow at a constant rate due to changes in the rates of resource extraction, unlike non-resource GDP, which does grow at a constant rate.

FIGURE 2: RESOURCE DIVIDEND AND FUND SIZE WITH DIFFERENT DEGREES OF PRUDENCE (EXTRACTION SCENARIO 1)

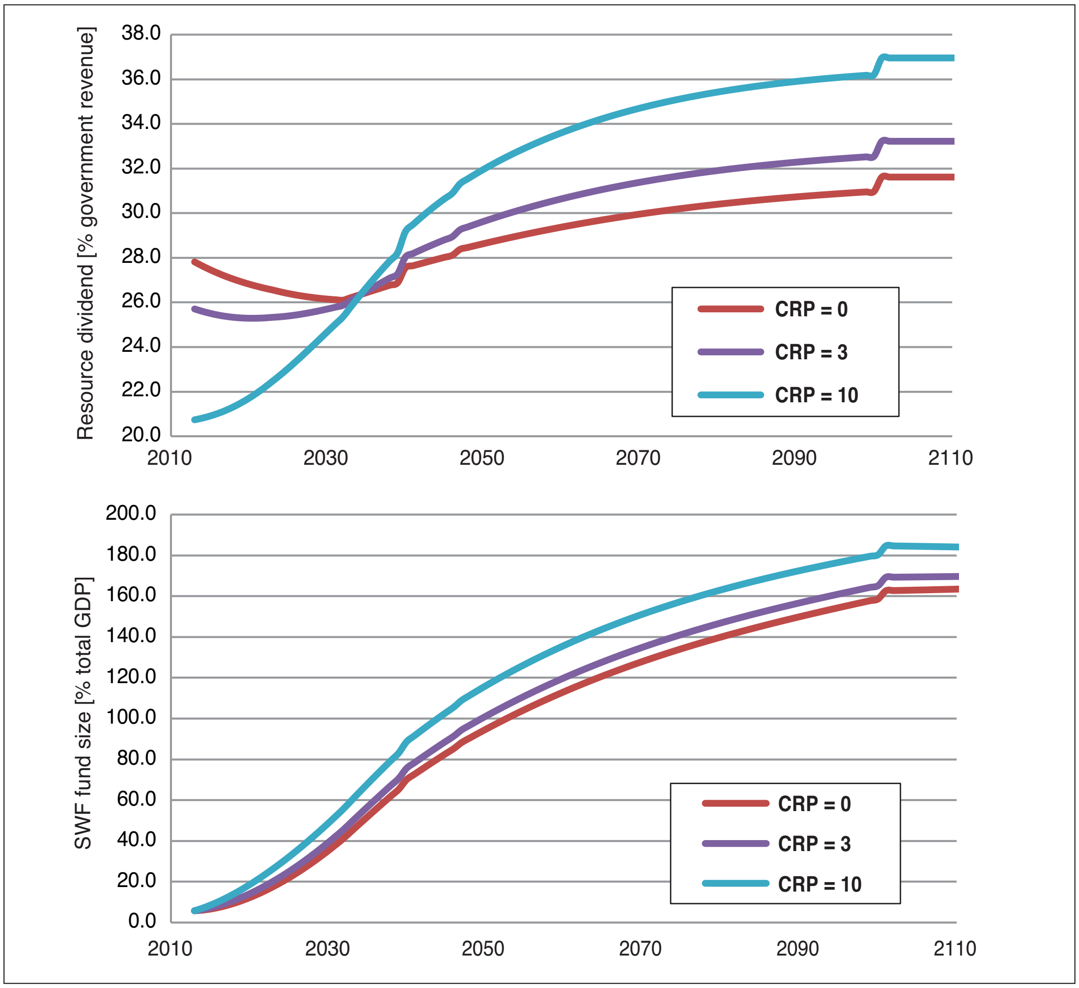


Table 2 reports the optimal fund sizes as percentage of GDP and the resource dividend as percentage of government revenue (GR) if the coefficient of relative prudence equals three. We also report in brackets our estimates for the optimal fund sizes and resource dividends in thousands of 2013 dollars (Canadian) per capita, corrected for productivity growth (the per capita fund sizes grow at the rate of two per cent per year).

We thus see that the total fund starts at about $4,500 per capita in 2013 (5.7 per cent of GDP) and grows to $32,600 per capita in 2030 (39 per cent of GDP) and then to $76,900 per capita in 2050 (101 per cent of GDP) and $117,000 per capita in 2100 (165 per cent of GDP) — all figures in 2013 constant dollars. This would sustain an annual resource dividend of $2,800 in 2013 (26 per cent of government revenue) and $3,200 per capita from 2050 onwards (about 30 per cent of public revenue).[16] This resource dividend in per capita terms is corrected for productivity growth too, so it in fact grows with the rest of the economy at a rate of 2.0 per cent per year. This means that the resource dividend and GDP grow between 2013 and 2050 by a factor of 2.1. Hence, in real terms, the uncorrected per capita resource dividend grows from $2,800 in 2013 to $6,600 in 2050.

[16] Since we have that government revenue as a percentage of non-resource GDP is constant and that resource rents decline, government revenue as a percentage of total GDP goes up a bit.

The total fund would grow from $45,800 per capita in 2030 to $161,200 per capita in 2050 (both in 2013 dollars), which amounts to, respectively, $224 billion and $1,020 billion in aggregate. A bold target of achieving, in real terms, net financial assets in the fund of at least $200 billion by 2030 (40 per cent of GDP) and $1 trillion by 2050 (100 per cent of GDP) will help to reinvigorate the Alberta Heritage Savings Trust Fund.

The final column of Table 1 reports the total saving as a percentage of government revenue (and in brackets the precautionary saving as a percentage of government revenue). Neither the intergenerational nor precautionary saving is a fixed proportion of government revenue. In the early years, saving is positive and rising, but in the latter half of the century, saving rates are negative. The growth in the proceeds from the fund takes over from the declining resource revenues.

TABLE 2: ESTIMATES OF THE OPTIMAL FUND SIZES AND SAVINGS FOR THE ALBERTA GOVERNMENT (*CRP* = 3 AND PRODUCTION SCENARIO 1)

Year	Intergenerational fund (per cent of GDP)	Liquidity fund (per cent of GDP)	Total fund (per cent of GDP)	Resource dividend (per cent of government revenue)	Saving (per cent of government revenue
2013	4.8% ($3,800 pp $3,800 pp)	0.9% ($700 pp ($700 pp	5.7% ($4,500 pp $4,500 pp)	26% ($2,800 pp $2,800 pp)	3.5%, 2.1% ($400 pp $400 pp)
2020	12% ($9,900 pp $11,000 pp)	1.9% ($1,500 pp $1,800 pp)	14.0% ($11,000 pp $13,000 pp)	25% ($2,900 pp $3,300 pp)	12%, 1.5% ($1,300 pp $1,500 pp)
2030	35% ($29,000 pp $41,000 pp)	4.0% ($3,400 pp $4,700 pp)	39% ($33,000 pp $46,000 pp)	26% ($3,000 pp $4,200 pp)	16%, 0.4% ($1,900 pp $2,700 pp)
2050	95% ($72,000 pp $151,000 pp)	6.4% ($4,900 pp $10,000 pp)	101% ($77,000 pp $161,000 pp)	30% ($3,200 pp $6,600 pp)	-6.7%, -1.0% (-$700 pp -$1,500 pp)
2100	159% ($112,000 pp $639,000 pp)	6.5% ($26,000 pp $148,000 pp)	165% ($117,000 pp $665,000 pp)	33% ($3,200 pp $18,400 pp)	-28%, 1.6% (-$2,700 pp -$16,000 pp)

Note: The size of the fund in 2013 is $17.6 billion. The size of resource wealth in 2013 is $1.24 trillion in 2013, which corresponds to $320,000 per capita, or 400 per cent of GDP. For comparison with the figures in the table, we must multiply this by 0.34, the share of resource rents that accrues to the government, to give $420 billion, $109,000 per capita, or 137 per cent of GDP. The first figures in brackets are dollars per person. They are corrected for productivity growth and thus grow at the rate of two per cent per year. The second figures in brackets are uncorrected for productivity growth. The figures in the last column report total and precautionary saving as percentage of government revenue; the figures in brackets are total saving, growth-corrected and uncorrected.

To get an idea of the quantitative magnitude of the resource dividend and the required fund size, it helps to compare our results for Alberta with those obtained earlier for Norway, Iraq and Ghana.[17] The per capita resource dividend of $2,800 (Canadian dollars) is much bigger than that for Ghana (US$37 per capita) and bigger than that for Iraq (US$1,528 per capita), but roughly a factor three smaller than that for Norway (US$8,537 per capita). The optimal final size of the intergenerational and liquidity fund sizes for Alberta in 2100 (159 per cent and 6.5 per cent of non-resource GDP) are rather less than the final fund sizes for Norway (677 per cent and three per cent of non-resource GDP) and very much smaller than those for Iraq (172 and 12 times non-resource GDP), but larger than those for Ghana (115 per cent and 0.2 per cent of GDP). Norway is perhaps the most natural comparison for Alberta. Natural resource revenues last longer in Alberta and therefore there is less need to smooth resource dividends across generations, so a relatively smaller fund is needed.

[17] van den Bremer and van der Ploeg, “Managing and.”

3.3. Comparison with the spend-all and bird-in-hand rules

Figure 3 compares the benchmark with relative prudence set to *CRP* = 3 and the intergenerational fund outcomes (i.e., *CRP* = 0) with the spend-all and bird-in-hand policies. The blue line "Spend all" shows resource rents as a percentage of government revenue and corresponds to the policy of spending all resource rents directly. This spend-all policy is suboptimal since it leads to volatile resource dividends. Moreover, spending is too high during the next two decades when the windfall is at its highest and declines too rapidly afterwards when the windfall revenue fades away. Welfare gains can be achieved by building an intergenerational fund to smooth the resource dividend across generations.

The orange lines in figures 3(a) and 3(b) illustrate what happens with a Norwegian style bird-in-hand rule, which does not allow the use of reserves as collateral, but puts all resource revenue in the fund and withdraws a fixed four per cent per year from the fund for general purposes. We see that under the bird-in-hand rule, wealth is accumulated much more quickly than under the optimal rule, even allowing for the effects of prudence and precautionary buffers (contrast with the red and purple lines).

FIGURE 3: SPEND ALL, PERMANENT-INCOME HYPOTHESIS AND BIRD IN HAND (EXTRACTION SCENARIO 1)

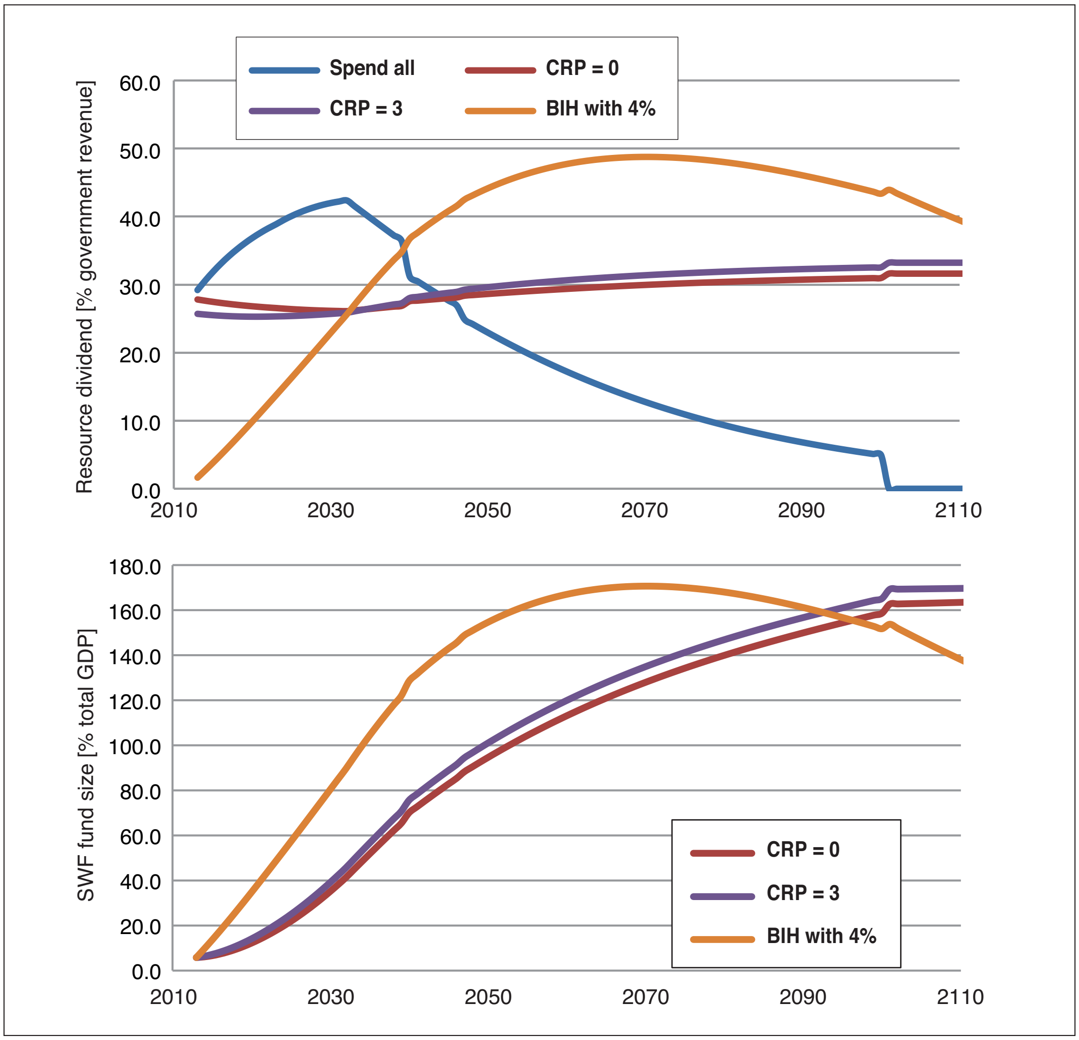
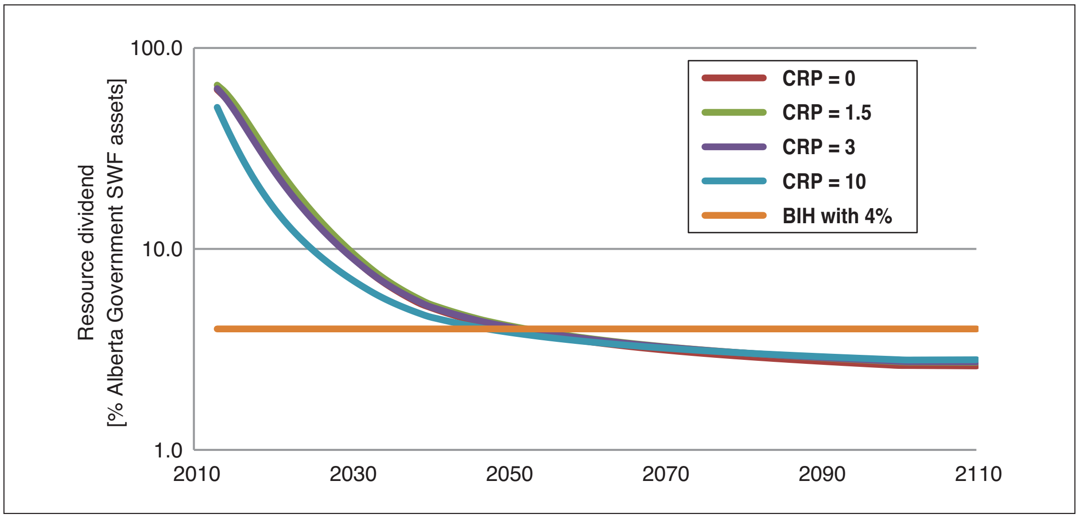


Figure 4 shows that, compared with the optimal policy, the resource dividends under the bird-in-hand rule are much too low in the initial periods during the windfall and too high once the windfall has faded away. The optimal policy thus spends a much larger percentage of the fund in the early years and a much lower percentage in later years compared to the bird-in-hand rule. Hence, given substantial amount of belowground natural resource wealth, it is sub-optimal to set the resource dividend (as Norway does) to a fixed percentage of aboveground financial wealth.

FIGURE 4: RESOURCE DIVIDENDS AS PERCENTAGE OF THE FUND

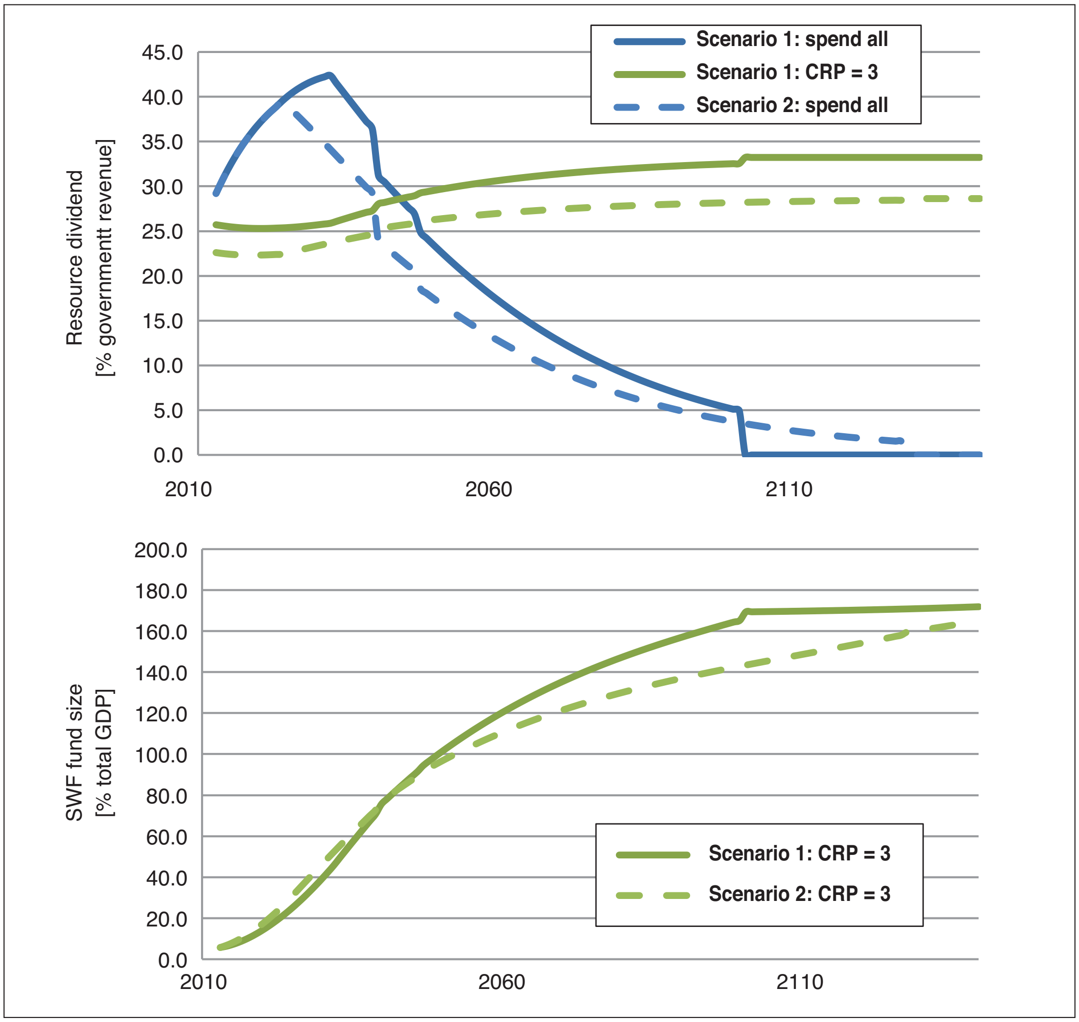


3.4. Alternative production scenarios

As discussed in Section 2, the timing of the windfall has important implications for optimal savings behaviour. A feature of the benchmark extraction scenario (scenario 1) is that rents reach a peak of approximately 40 per cent of government revenue in 2030. Such an increase reduces the need for intergenerational saving. In the alternative production scenario for bitumen, production reaches a plateau in 2022 (at the end of official projections) and continues from then on at the constant rate of 1.4 billion barrels per year until exhaustion, which occurs a few decades later than in the benchmark scenario.

The dashed- and solid-green lines in Figure 5 (first panel) illustrate the effects on the optimal spending increment: initially this drops from 26 per cent under scenario 1 to 23 per cent of government revenue under scenario 2 (with *CRP* = 3). Since, in the alternative scenario, the windfall is more spread out with less revenue coming in the near future and more coming in the distant future, a smaller fund has to be built up in the long run. However, more funds have to be accumulated in the short run as production reaches a plateau earlier. The dashed- and solid-green lines in Figure 5 (second panel) illustrate the effects on the total fund (*CRP* = 3) for the two scenarios.

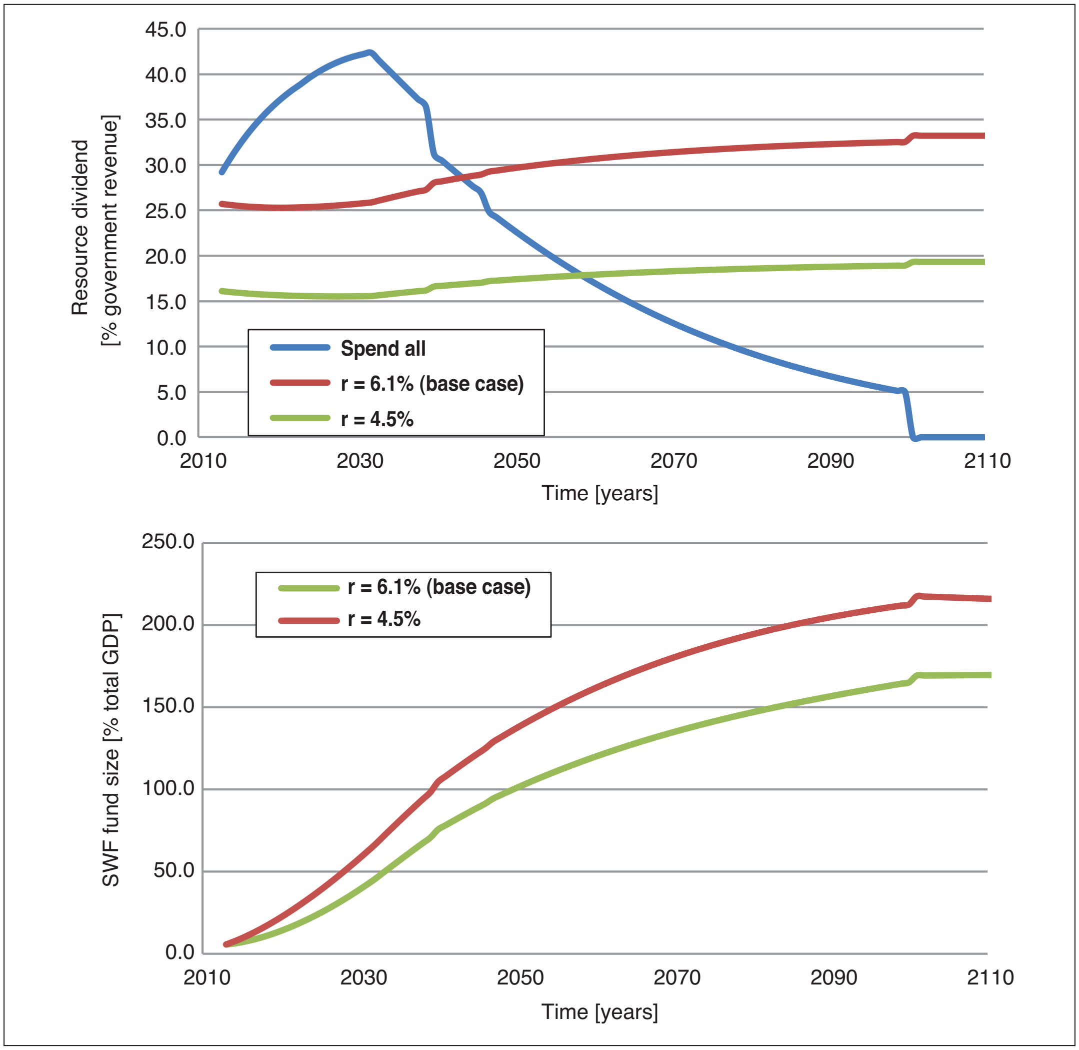
FIGURE 5: OPTIMAL SPENDING AND BUILD-UP OF FUND FOR DIFFERENT EXTRACTION SCENARIOS (*CRP*=3)



3.5. Effects of a lower real return on assets

Our benchmark choice for a real interest rate of 6.1 per cent per year is perhaps somewhat high, especially given the government's assumption that the rate of return is 4.5 percentage points above the Canadian Consumer Price Index. Our choice reflects the rate of return during the last decade, while the government's assumption is more in line with real returns over the longer term. Since the choice of interest rate influences the outcome, Figure 6 shows the effects of a real rate of return of 4.5 per cent per year. Not surprisingly, we see that using a lower real return on assets depresses the resource dividend in the long run, from 33 per cent to 19 per cent of government revenue. It also leads to a bigger accumulation of assets and thus to a bigger size of the fund. The fund size in 2100 is now 215 per cent rather than 165 per cent of GDP.

FIGURE 6: EFFECTS OF A LOWER REAL RETURN ON FUND ASSETS



3.6. Correlation between gas and oil prices

Short-term instability of revenue in Alberta can often be driven as much by fluctuations in gas prices as by fluctuations in bitumen prices. This is why it is important to stabilize revenue through resource diversification. Empirically, there has been a high degree of negative correlation between oil and gas prices. Although it is possible to allow for this correlation, we find that the effect is quantitatively not very important, as resource rents for natural gas only make up a small part of total resource rents, especially given that recent natural gas prices have been quite low. For example, if the correlation coefficient between gas and oil prices is taken to be -0.5 instead of 1.0, then the resource dividend as a fraction of public revenue and the fund size as a percentage of GDP are hardly affected.

4. WHAT ASSETS SHOULD BE HELD IN THE FUNDS

4.1. Diversification and leveraging-up holdings of risky assets

Careful choice of assets purchased as part of the sovereign wealth portfolio has the potential of hedging part of the risk associated with oil price volatility. Should the fund invest more in equity holdings of companies that perform poorly when oil prices are high, or in companies that benefit from increases in oil prices? Examples of the former are intensive-energy users such as aluminium smelters or steel producers, while examples of the latter are companies that offer substitutes for fossil fuels or produce energy efficient cars. When investing in companies whose share prices vary inversely (rather than positively) with the price of oil, the residual risk that is faced by the fund managers is less, since those shares hedge part of the risks associated with oil- and gas-price volatility. Hence, they need to hold smaller precautionary buffers.[18]

The problem of optimal portfolio management can be separated into two parts. First, the size of the risky portfolio relative to the total portfolio (i.e., the share of stocks and other risky assets relatively to total belowground resource wealth and aboveground financial wealth) depends on two factors: it is lower if the intolerance for risk is higher; and it increases in proportion to the average excess return of the market. The risky portfolio is made up of stocks and other risky assets, whereas the safe portfolio consists of government bonds. The share of the risky portfolio in the total portfolio might well exceed 100 per cent, in which case the fund managers take a short position by borrowing in the risk-free asset. Second, independent of the degree of risk intolerance, the portfolio share of each risky asset depends on the expected own excess return over the market rate of return and on the covariance with the excess returns of the other assets. In non-technical terms this means that one invests more in a particular asset if it has a relatively high return compared with other assets, the volatility of the return is relatively low, and the asset is good at hedging other risky assets. Crucial for funds dependent on oil and other natural resources is that the holdings of each risky asset are leveraged with a factor that depends on the ratio of belowground resource wealth to aboveground financial wealth. As natural resource reserves are depleted, holdings of risky assets are deleveraged and thus fund managers invest more in safe assets.

Once the portfolio allocation is determined, consumption adjusts to the risk in the portfolio through precautionary saving. The extent of this precautionary saving is bigger if fund managers are more prudent, the share of risky assets in the portfolio is higher, and the residual unhedged volatility of the portfolio is substantial. Precautionary buffer stocks are thus built up to cope with the residual, non-diversifiable risk of the portfolio. The resource dividend is a constant proportion of the size of the portfolio where this proportion is smaller than without asset price volatility to reflect the precautionary saving response.

[18] A. Gintschel and B. Scherer, "Optimal asset allocation for sovereign wealth funds," *Journal of Asset Management* 9, 3 (2008): 215-238. R. Scherer, "Portfolio Choice for Oil-Based Sovereign Wealth Funds" (Nice, France: EDHEC-Risk Institute, EDHEC Business School, 2009); T.S. van den Bremer, F. van der Ploeg and S. Wills, "The Elephant in the Ground: Managing Oil and Sovereign Wealth," Research Paper 129 (Oxford: University of Oxford, Oxford Centre for the Analysis of Resource Rich Economies, 2014).

Extending the modern approach to capital-asset pricing theory to allow for oil- and gas-price volatility and asset-return volatility thus gives important insights. First, more is invested in all risky assets. Second, a short position is taken in risk-free assets and more is invested in risky assets that are negatively correlated with the returns on oil, gas and bitumen to hedge the risk of oil-, gas- and bitumen-price volatility. For example, one might invest relatively high proportions in companies producing plastics, aluminium and steel, which are energy-intensive industries and whose returns are negatively correlated with oil prices. Conversely, one might invest less in industries producing renewable energy, as their returns are positively correlated with oil prices.[19] Third, as natural resource reserves are depleted, this short position is unwound. Fourth, precautionary saving copes with the residual, non-diversifiable oil price risk, which is especially large if markets are incomplete. Fifth, per capita total wealth and the resource dividend rise steadily over time due to the accumulated precautionary saving buffers.

4.2. Problems with hedging oil price volatility

Of course, one might argue that a good alternative to diversification is to insure against future oil price volatility by using options to hedge against this considerable risk. In a perfect world with frictionless markets and without capital scarcity or asymmetric information, hedging and using a stabilization or liquidity fund are equivalent. However, in practice, futures markets are too thin, especially for the large sums and long horizons involved here, and too costly for hedging to be an attractive option. Furthermore, hedging is politically risky. It will be hard to convince citizens that money invested in a hedge to protect against falling oil prices is well spent if oil prices consequently do not fall, since the money might be better spent on education, housing or health. One thus has to cope with a large amount of non-diversifiable oil price risk by accumulating precautionary buffers in a liquidity fund, so that with a positive shock to the world oil price, extra revenue is channeled towards the fund, and with a negative shock, the fund helps to mitigate the falls in revenue.

Of course, flexible labour supply, good markets and avoiding irreversible commitments also help improve preparations for oil price volatility. One could also relate debt payments to the price of oil, which means that provincial government bonds contain a clause that ties principal and interest payments to the price of oil. This implies that in the event of a crash in oil prices, the debt burden falls as well. Finally, one can diversify the economy into sectors whose fortunes are negatively correlated with the bitumen sector.

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[19] If market values of oil reserves and the fund are equal, relatively coarse partitions of the Morgan Stanley Capital International indices suggest that the certainty-equivalent return is 3.3 per cent per annum (0.5 per cent if short sales are not allowed) higher than if oil wealth is not taken account of. Gintschel and Scherer, "Optimal asset."

5. CONCLUSION

Alberta requires strong and credible legislation to reinforce Alberta's commitment to saving — a need that is strong now, but will only increase in importance. This will lead to a strong sovereign wealth fund (the "fund") to manage the revenue from its bitumen, oil and natural gas revenues. The fund's day-to-day management should be independent from the Alberta government, with a clear mandate on how it should be run. These mandates should include guidelines on the following matters:

1. **The size of the resource dividend from the fund that can be used each year to finance government spending or tax cuts.**[20] A rough estimate of what might be affordable is about $2,800 per capita per year in 2013 growing in real terms at two per cent per year or, equivalently, about 30 per cent of government revenue. This resource dividend should not be a constant fraction of the size of the fund, as is done with Norway's bird-in-hand rule. It should be a constant fraction of total aboveground (i.e., the fund) wealth and belowground wealth, adjusted slightly for precautionary reasons.

2. **How much to channel into the fund for intergenerational and liquidity purposes.** Most of the saving channelled into the fund will be to smooth public and private consumption per capita (corrected for productivity growth). This would lead to a growth in the fund from 5.7 per cent of GDP in 2013 to 39 per cent of GDP in 2030, 101 per cent of GDP in 2050, and 165 per cent of GDP in 2100. A bold target corresponding to a degree of relative prudence of three must lead to a size of net financial assets in the fund of $46,000 per capita in 2030 and $161,000 per capita in 2050 (both in 2013 dollars and not corrected for growth). This is equivalent to having a target fund in the aggregate of at least $200 billion by 2030 and $1 trillion by 2050, compared to the $17.6 billion that the fund held as of March 2013. Such a bold target helps to reinvigorate the Alberta Heritage Savings Trust Fund and the Contingency Account. The component of the fund that is needed to cushion against oil price volatility — the Contingency Account — is important, but it only plays a leading role in the early years, unless policy-makers are very prudent.

3. **What kind of assets to invest in the fund.** The portfolio of assets should be fully diversified, both internationally and across different types of asset groups. The large amount of belowground resource wealth necessitates that the optimal holdings of risky assets should be leveraged-up with a factor equal to the ratio of oil wealth to fund wealth, if necessary by going short and taking a negative position in the safe asset. Even if going short is infeasible, one can improve the return on the fund by leveraging-up all holdings of risky assets in the portfolio and thus holding fewer of the safe assets. The leveraging-up of risky assets in the fund's portfolio will be gradually undone as subsoil wealth is depleted. Hedging requires more holdings of assets that contribute to offset the risk of oil price volatility, such as shares of aluminium processors. It may be practical to have a mandate for a percentage of assets that tracks a share index and to have this percentage decline as oil wealth declines.

[20] To avoid political turmoil, it is advisable to have agreement at the beginning of each period of government on how much of the resource dividend to designate for public spending and how much for private spending.

4. **No need for an investment fund.** There is no need to spend any part of the fund on public investment projects, since Alberta has good access to international capital markets and does not suffer from capital scarcity. There is thus no need for a separate Alberta Heritage Capital Fund that would focus on investment in the Alberta economy. Such funds carry at best the danger of improper calculation of costs and benefits, and at worst the danger of political manipulation.

The qualitative implications of these policy recommendations are what matters. The figures reported are only indicative and depend on our chosen assumptions. For example, if fund managers adopt a lower real return of 4.5 per cent per year instead of our benchmark assumption of 6.1 per cent per year, the resource dividend will not be 30 per cent but approximately 20 per cent of government revenue and the fund size at the end of this century will not be 165 per cent but 215 per cent of GDP.

Following Ossowski,[21] Kneebone[22] and the Alberta Financial Investment and Planning Advisory Commission,[23] these recommendations might provide a basis for more transparent and less volatile budget planning and prudent stewardship of Alberta's non-renewable resources by providing the greatest returns on the savings for current and future generations of Albertans in the face of oil-price and asset-price uncertainty. We have one proviso to make: We have assumed that the resource dividend is indexed to wages and productivity as is typical for welfare benefits. However, it may be politically imperative to have a resource dividend that is not indexed and is constant in per capita terms. The case for building a large fund is then much weakened and, in fact, our calculations show that it is necessary to borrow with future growth as collateral instead of a fund for all but very high indexation rates of the "dividend." Since such borrowing is infeasible, we ignore the constant-resource dividend case and have focused on the case where the resource dividend grows at the same rate as the rest of the economy. Finally, our estimates for precautionary saving provide a lower bound, as uncertainty surrounding the size of the reserves, future technologies, future extraction and transportation costs, future costs of carbon and the consequent extraction path in the long term provide a considerable source of uncertainty, perhaps on a par with that of the price.

In contrast to earlier proposals from the Mintz commission,[24] we do not advocate saving a fixed percentage of Alberta's resource revenue each year. Neither do we recommend consuming a fixed proportion of the fund as is practice in Norway.[25] Instead, the resource dividend should be a fixed percentage of total below- and aboveground wealth. This ensures that the dividend grows in line with GDP. In addition, we warn against a special fund for

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[21] R. Ossowski, "Oil Funds. Conceptual Framework and Selected International Experience," in *Alberta's Volatile Government Revenues — Western Studies in Economic Policy No. 8*, ed. L.S. Wilson (Edmonton, Alta.: Institute for Public Economics, University of Alberta, 2002).

[22] R.D. Kneebone, "From Famine to the Feast: The Evolution of Budgeting Rules in Alberta," *Canadian Tax Journal* 54, 3 (2006): 657-673.

[23] Alberta Financial Investment and Planning Advisory Commission, *Preserving Prosperity*.

[24] ibid.

[25] S. Landon and C. Smith ("Government revenue stabilization funds: do they make us better off?" *Canadian Journal of Public Policy* 39, 1 (2013): 71-99) advocate a rule that would deposit half of revenues in the fund and set resource dividends at 25 per cent of the fund. Norway deposits all revenues in its fund and withdraws four per cent of the fund each year. Such rules may be suboptimal and are not sustainable in the long run.

investment in the Alberta economy as this would come at the expense of a proper analysis of the costs and benefits of such investments. The decision to invest in domestic assets should be solely based on a cost-benefit analysis, the outcome of which is independent of the availability of oil, gas and bitumen proceeds, and can be financed by borrowing on international capital markets.

These recommendations are designed to raise the profile of the Alberta Heritage Savings Trust Fund. The precise details of the stewardship of the fund should be further worked out to establish a clear and effective approach to governance and policy-making. It should also free up political time and effort to devote to the difficult task of how to sustain the Alberta economy after the resource windfall has ceased. This requires large-scale transformation of belowground bitumen, oil and gas assets into long-lasting financial assets and a viable economy after the windfall.

APPENDIX A:

HOW TO DERIVE THE RESOURCE DIVIDEND AND SAVINGS IN THE INTERGENERATIONAL FUND

Here we focus on savings in the intergenerational fund and therefore abstract from oil-price and asset-price volatility. We assume here that the return on foreign assets r is given on the international capital markets. We also assume that the marginal cost of extracting one unit of resources is fixed. The fund acts to smooth the resource dividend, and thus the boost to public or private consumption, over time. The utility of each citizen increases at a decreasing rate in the resource dividend he or she receives. The government must decide how much to save and how much to spend. It does this by adopting a utilitarian welfare perspective that corresponds to maximizing the sum of the discounted utilities of all citizens, both those currently alive and those alive in the future, where the social discount rate is denoted by $\varrho > 0$. Maximizing utilitarian welfare (see (B1)) is done subject to the budget constraint

(A1) $$\dot{F} = rF + \Omega - D, \quad F(0) = F_0,$$

where F denotes fund size, Ω the resource rent, and D the aggregate resource dividend. This gives the Keynes-Ramsey rule (or Euler equation) for the growth rate in the per capita resource dividend:

(A1) $$\frac{\dot{D}}{D} - n = \theta(r - \varrho),$$

where $\theta > 0$ is the elasticity of intertemporal substitution and n the rate of population growth. The coefficient of relative intergenerational inequality aversion equals $1/\theta$. The time path for consumption per capita is steeper with saving taking place if the interest rate exceeds the discount rate. By substituting (A1) into the present-value budget constraint and solving, we find that the optimal resource dividend is a constant fraction of the total wealth:

(A2) $$D(t) = [r - \theta(r - \varrho) - n]\,[F(t) + V(t)], \qquad V(t) \equiv \int_t^{\infty} e^{-r(\tau - t)}\,\Omega(\tau)d\tau.$$

where resource wealth V is defined as the present value of resource rents. More inelastic demand for natural resources, lower extraction costs, and bigger reserves imply larger resource wealth.

Although choosing the social discount rate involves intricate intergenerational equity considerations, we adopt a pragmatic approach. This rate is chosen so that the resource dividend, and thus the total of financial and resource wealth (from (A2)), grows at the same rate as the rest of the economy. Since $\dot{V} = rV - \Omega$ and thus $\dot{F} + \dot{V} = r(F + V) - D$, we have

$$\frac{\dot{F} + \dot{V}}{F + V} = r - \frac{D}{F + V} = \theta(r - \varrho) + n \quad \text{(from (A2))}.$$

Denoting per capita growth rate of GDP by $g > 0$, the growth rate in GDP, the resource dividend and total wealth equals $g + n$. Hence, we must set the social discount rate to $\varrho = r - g/\theta < r$. The discount rate has to be lower in a growing economy to ensure that indeed more saving takes place and the per capita resource dividend grows over time. If it is easier to substitute present for future consumption (high θ), this correction term can be smaller.

It follows from (A2) that with this choice for the discount rate the propensity to consume out of total wealth equals $r - \theta(r-\varrho) - n = r - g - n$. Both the resource dividend and total wealth per capita grow at the rate of productivity growth g. As fraction of GDP they are fully smoothed across different generations. This implies that falls in resource wealth are fully compensated for by increases in fund wealth. This is the famous Hartwick rule:[26] belowground assets must be fully converted into aboveground assets so that total wealth is unchanged.[27]

The *permanent* component of resource revenue is the annuity value of the stream of current and future resource revenue, which is simply the interest (corrected for the trend growth rate) on resource wealth $(r - n - g)\,V$. The *temporary* component of resource revenue is current revenue minus permanent revenue. If resource revenue is expected to increase (decrease) over time, temporary revenue is negative (positive). We thus have the following guidelines for managing resource wealth:

(i) Net saving into the fund should react to the temporary component of resource revenue. Hence, if revenue is expected to increase, one should borrow to make sure current generations benefit from future revenue. If revenue is expected to drop, one should save in order that future generations benefit from the current boom in resource revenue.

(ii) The quicker the depletion of resources from the crust of the earth, the quicker the fall in revenue and the bigger the proportion of the windfall should be saved.

(iii) The resource dividend should be a fixed proportion of total wealth. This implies that it goes up and down with the permanent component of revenues, not with current revenue.

To illustrate, consider a bitumen windfall that declines exponentially at the rate $\omega > 0$. The permanent and temporary fractions of this windfall are then

$\frac{r-n-g}{\omega + r - n - g}$ and $\frac{\omega}{\omega + r - n - g}$, respectively. The fraction of the current windfall that should be saved should thus be $\frac{\omega}{\omega + r - n - g}$. We thus see that a bigger proportion of the windfall is saved if the windfall is rapidly declining (corresponding to a high value of ω). For the extreme case of a permanent windfall (with $\omega = 0$), none of the windfall must be saved. At the other extreme, as the duration of a windfall vanishes ($\omega \to \infty$), all of the windfall should be saved.

These guidelines can also be used to indicate how a *temporary* and *anticipated* resource windfall corresponding to zero revenue from time T onwards should be managed. This permits us to highlight the case for an intergenerational sovereign wealth fund. To achieve smoothing of the resource dividend as fraction of non-resource GDP across different generations, a temporary and anticipated windfall with revenue ceasing after time T necessitates borrowing ahead of the windfall, repaying debt and interest followed by building up assets during the oil windfall, and spending the income from accumulated assets after the windfall. Such a policy has the effect of smoothing both the resource dividend and total wealth per citizen. Hence, any

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[26] J.M. Hartwick, "Intergenerational Equity and the Investing of Rents from Exhaustible Resources", *American Economic Review* 67, 5 (1977): 972-974.

[27] F. van der Ploeg, "Guidelines for Exploiting Natural Resource Wealth," *Oxford Review of Economic Policy* 30, 1 (2014): 145-169.

fall in belowground bitumen wealth is compensated by a matching increase in aboveground financial wealth. For example, in the run up to the windfall borrowing must exactly be matched by the increase in resource wealth (i.e., the present discounted value of the windfall) as a result of it becoming closer and thus being subject to less severe discounting. During the windfall the paying off of debt and building up of financial assets into an intergenerational sovereign wealth fund is exactly matched by the reduction in belowground resource wealth resulting from depletion. After the windfall, belowground resource wealth is zero and thus, aboveground financial wealth must be constant and equal to initial resource wealth. One withdraws an annuity each year from the fund, which in per capita terms grows at the rate of productivity growth.

OTHER CHOICES OF DISCOUNT RATES

Our pragmatic choice for the discount rate has its merits, but two other outcomes leading to higher discount rates should be kept in mind to. First, an alternative is to set the discount rate equal to the market rate of interest, i.e., $\varrho = r$. This ensures that the per capita resource dividend is *constant*. This choice requires a higher discount rate, since future generations will not enjoy growing resource dividends. This may seem fairer, but may be difficult to realize in practice as it requires borrowing with future growth as collateral. If it would be possible to do this, the rationale for an intergenerational fund is reduced considerably.

Second, if incumbent politicians are motivated by the desire to secure re-election, the discount rate can be much higher than the market rate of return on financial assets. The propensity to consume out of wealth is then higher and the economy saves less and gets poorer with passage of time. This effect will be less pronounced if politicians have a high willingness to substitute present for future consumption as indicated by a low elasticity of intergenerational inequality aversion.

APPENDIX B:

TECHNICALITIES OF VOLATILE OIL PRICES AND OPTIMAL SAVING IN THE LIQUIDITY FUND

Here we extend Appendix A to allow for volatile oil and asset prices, and we also allow for non-resource income. The non-resource part of the economy grows at a deterministic rate $g + n$, where g is the growth rate of total factor productivity and n the population growth rate. The (log of the) oil price is captured by a first-order autoregressive stochastic process with a large degree of persistence. The key equations are given in section B.1 below, not normalized or expressed in efficiency units. Section B.2 discusses the intuition of the precautionary-saving rule. Section B.3 offers an extension that enables prudent forecasts of economic growth based on historical data for Alberta.

B.1. Deterministic economic growth

With time-separable utility, the representative Albertan consumer maximizes:

(B1) $$J(t,F,P,Y) = \max_{c} E_t \left[\int_t^{\infty} U\big(D(\tau) / L(\tau)\big) L(\tau)\, e^{-\varrho(\tau-t)} d\tau \right]$$

subject to the wealth-accumulation constraint

(B2) $$\frac{dF}{dt} = rF + \Omega + Y - D,$$

where D denotes the aggregate resource dividend, L total population, and Y non-resource income. Total assets F are accumulated at the (deterministic) interest rate r. Natural resource rents are:

(B3) $$\Omega(t) = \sum_{i\,=\,\text{bitumen, crude oil, natural gas}} \big(P_i(t) - \lambda_i\big) O_i(t),$$

with P_i denoting the price (in C.$/b.o.e.), λ_i the constant unit extraction costs (in $CDN/b.o.e.) and O_i the extraction rate (in b.o.e./year). We allow for separate extraction rates, prices processes and extraction costs for bitumen, crude oil and natural gas. Once all resources have been extracted, these could in principle find productive use in the non-resource part of the economy. The Euler equation for optimal consumption corrected for prudence and volatile energy prices is:

(B4) $$\frac{1}{dt} E_t \big[dD\big] = \big[\theta\,(r - \varrho) + n\big]\, D + \frac{1}{2}\, CRP\, \sigma_D^2\, D,$$

where θ is the elasticity of intertemporal substitution, *CRP* the coefficient of relative prudence and σ_D the volatility of total consumption:

$$(B5) \qquad D^2\sigma_D^2 = \left(\frac{\partial D}{\partial P_B}\right) P_B^2\,\sigma_B^2 + \left(\frac{\partial D}{\partial P_O}\right) P_O^2\,\sigma_O^2 + \left(\frac{\partial D}{\partial P_G}\right) P_G^2\,\sigma_G^2 + 2\,\frac{\partial D}{\partial P_B}\frac{\partial D}{\partial P_O} P_B P_O \varrho_{BO}\sigma_B\sigma_O$$

$$+\, 2\,\frac{\partial D}{\partial P_B}\frac{\partial D}{\partial P_O} P_B P_G \varrho_{BG}\sigma_B\sigma_G + 2\,\frac{\partial D}{\partial P_B}\frac{\partial D}{\partial P_O} P_O P_G \varrho_{OG}\sigma_O\sigma_G,$$

where σ_B, σ_O and σ_G denote the volatilities of the prices of bitumen, crude oil and natural gas respectively. The correlations are ϱ_{BO}, ϱ_{BG} and ϱ_{OG}. To evaluate the marginal propensities to consume out of a price shock $\partial D/\partial P_i$, we use the solution to the deterministic problem:

$$(B6) \qquad D(t) = \left[r - \theta\,(\mathrm{r} - \varrho) - n\right]\,\left[F(t) + \int_t^\infty \left(\Omega(\tau) + Y(\tau)\right)e^{-r\tau} - d\tau\right].$$

Our estimates of the optimal fund sizes suppose that the resource dividend is smoothed in efficiency units, which amounts to setting $\varrho = r - g/\theta$. Equation (B4) then simplifies to $E_t\,[d\hat{C}]/dt = 0.5CRP\sigma_C^2\hat{C},$ where the hats indicate that consumption is expressed in efficiency units (i.e., normalized for productivity growth and population growth).

B.2. Interpretation

The Euler equation (B4), also known as the Keynes-Ramsey rule, allows for prudence and implies that the expected growth in consumption is not zero, but positive. It is optimal to accumulate precautionary buffers initially by running surpluses; these buffers then act as insurance against future drops in oil prices. The extent of this precautionary saving and the resulting magnitude of the precautionary buffers that are being accumulated are larger if the coefficient of relative prudence and relative volatility of commodity prices are substantial. Furthermore, the expected growth in consumption and the resulting degree of precautionary saving are higher if oil price shocks are less transient as a greater part of the revenue resulting from shocks is saved if these shocks are more permanent. Thus, if shocks are permanent, all expected future prices increase by the same amount as the initial shock and the required precautionary buffers will be large. If shocks are purely transient, they have no effect on future expected oil prices and there will be no precautionary saving. In general, with mean reversion, the effect of current oil price shocks on expected values of future price shocks is positive but less than one and the effect on precautionary saving is smaller. Finally, there is less need for precautionary saving if productivity growth makes a country richer in the future and is hence better able to deal with future income shocks. Although we highlight the need for precautionary saving by the government, one can also focus on the need for current account surpluses induced by precautionary saving in a small open economy.[28]

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[28] See, for example, R. Bems and I. de Carvalho Filho, "The Current Account and Precautionary Savings for Exporters of Exhaustible Resources," *Journal of International Economics* 84, 1 (2011): 48-64.

B.3. Stochastic economic growth

Consider a geometric Brownian motion for Alberta's non-resource GDP:

(B7) $$dY = N\Big((n + g)Ydt,\ Y^2\sigma_Y^2 dt\Big),$$

where σ_Y is the relative volatility of non-resource GDP. Subtracting resource rents from total GDP, gives growth rates for GDP per capita of 3.2 per cent for the last 10 years and 3.0 per cent for the period for which we have calculated resource rents (17 years). Corresponding volatility estimates are $\sigma_Y = 0.062$ for both periods. Ignoring possible correlations between non-resource GDP and the resource price processes, one needs to have $\left(\frac{\partial D}{\partial Y}\right)^2 Y^2 \sigma_Y^2$ as an additional term in (A5) whilst we use (A6) to get $\frac{\partial D(t)}{\partial Y(t)} = \frac{r - \theta(r - \varrho) - n}{r - n - g}$. If $\varrho = r - g/\theta$, we have $\partial D/\partial Y = 1$ and get:

(B4′) $$\frac{1}{dt}E_t\,[dD] = n + g + \Bigg[\underbrace{\frac{1}{2}CRP\sigma_D^2}_{\text{Prudent resource rent correction}} + \underbrace{\frac{1}{2}CRP\left(\frac{\sigma_Y Y}{D}\right)}_{\text{Prudent growth correction}}\Bigg]D.$$

In the long run $D = Y$ and the prudent growth correction is $CRP\sigma_Y^2/2 = 0.19\,CRP$. Hence, the prudent growth-correction term varies from 0.19 per cent per annum if $CRP = 1$ to 1.9 per cent per annum if $CRP = 10$. For $CRP = 3$, we get a growth correction term of 0.57 per cent per annum.

APPENDIX C:
DESCRIPTION OF THE DATA

C.1. Real interest rates

Over the 2002–2012 period, the average real annual rate of return on the Alberta Heritage Savings Trust Fund was 6.1 per cent with a nominal rate of return of 8.1 per cent[29] and average inflation in that period of 2.0 per cent[30] compared to 3.7 per cent for the Norwegian Pension Fund Global over the same period.[31] (The average real annual interest rates on Canadian and U.S. government bonds with maturities of one year, 5 years and 10 years over the same period were 0.4 per cent for Canadian and -0.6 per cent for U.S.; 1.1 per cent for Canadian and 0.4 per cent for U.S.; and 1.7 per cent for Canadian and 1.2 per cent for U.S.).[32] For the 1992–2012 period, the same rates were 1.9 per cent for Canadian (0.8 per cent U.S.), 2.7 per cent (1.7 per cent) and 3.2 per cent (2.7 per cent). The average real annual interest rates paid on Alberta provincial debt over the period 2005–2012 were 0.1 per cent, 1.3 per cent and 2.2 per cent on bonds with maturities of one year, 5 years and 10 years respectively,[33] so the return on the Alberta Heritage Savings Trust Fund was much higher than it was on bonds. We have set r = 6.1 per cent per year.

C.2. Estimates of reserve stocks

We use "remaining established reserves" as defined in the ST98 documents provided by the Alberta Energy Regulator ("recoverable quantities known to be left"), which is our main data source provided by the Department of Energy. This corresponds roughly to proven reserves. We then allow for discoveries based on historical data. At the end of 2012, remaining established reserves are:[34]

- Bitumen (or oilsands): 168 billion barrels.
- Conventional oil (light and heavy crude): 1.7 billion barrels
- Natural gas: 5.8 billion barrels of oil equivalent (916 billion SM3).

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[29] Alberta Treasury Board and Finance, Heritage Fund Annual Report 2012-2013, www.finance.alberta.ca/business/ahstf/publications.html.

[30] Statistics Canada, Cansim Online Statistics Database (2013), http://www5.statcan.gc.ca/cansim/home-accueil?lang=eng&p2=49&MM.

[31] Norges Bank Investment Management, Annual Report 2012, http://www.nbim.no/Global/Reports/2012/Annual%20report/Annual%20report%202012.pdf.

[32] Bank of Canada, Private Communication (2013); Statistics Canada, Cansim Online Statistics Database (2013); U.S. Federal Reserve, "Historical data on selected interest rates," (Washington, D.C.: 2013), http://www.federalreserve.gov/releases/h15/data.htm.

[33] Alberta Treasury Board and Finance, Private Communication (2013).

[34] Energy Resources Conservation Board (ERCB), "ST98-2013 Alberta's Energy Reserves 2012 and Supply/Demand Outlook 2013–2022" (2013), http://www.aer.ca/data-and-publications/statistical-reports.

We obtain the following R/P (reserves to production ratios) for 2012:

- **Bitumen:** at 2012 production rates of 0.72 billion bbl/year, we obtain a R/P ratio of 230 years. We do not allow for future discoveries.
- **Conventional oil** (encompassing light, heavy, and crude oil): at 2012 production rates of 0.20 billion bbl/year we obtain an R/P ratio of 8.5 years. Although for conventional oil there are significant new discoveries over many decades, production has only marginally exceeded new discoveries in the last 10 years with 10-year averages (20-year) of 0.19 (0.25) and 0.20 (0.20) billion bbl/year, respectively. To reflect this, we assume discoveries decline linearly from 0.20 billion bbl/year to zero in 30 years and increase the current reserves by 3.0 billion barrels accordingly.
- **Natural gas:** at 2012 production rates of 0.59 billion b.o.e./year, we obtain an R/P ratio of 10 years. We note significant new discoveries. Production has marginally exceeded new discoveries during the last 10 years with 10-year averages (20-year) of 0.78 (0.82) and 0.64 (0.60) billion b.o.e./year, respectively. We thus assume discoveries decline linearly from 0.64 billion b.o.e./year to zero in 30 years and increase current reserves by 9.6 billion b.o.e.

We exclude gas from oil wells (circa 10 per cent) and other natural resources such as coal and sulphur. Including our estimates for new discoveries, we use the following reserve estimates:

- Bitumen: 168 billion barrels.
- Conventional oil (light and heavy crude): 1.7 + 3.0 = 4.7 billion barrels.
- Natural gas: 5.8 + 9.6 = 15.4 billion b.o.e.

C.3. Official projections of extraction rates

Official projections are available until 2022.[35] In these official projections:

- **Bitumen** (or oilsands): production rates almost double and reach 1.4 billion bbl/year in 2021 from 0.72 billion bbl/year in 2012.
- **Conventional oil:** production rates decline marginally from 0.20 billion bbl/year in 2012 to 0.17 billion bbl/year in 2022.
- **Natural gas:** production rates decline from 0.58 billion b.o.e./year in 2012 to 0.44 billion b.o.e./year in 2022.

We use these official projections until 2022 and from then on we assume:

- **Bitumen** (or oilsands): in the *base* scenario a continued linear increase of the production rate until 2.0 billion bbl/year in 2030 followed by a plateau at this rate of production until exhaustion in 2100; in the *alternative* scenario production reaches a plateau in 2022 and continues at the constant rate of 1.44 bbl/year until exhaustion at a later time.
- **Conventional oil:** continued flat rate of production of 0.17 billion bbl/year until exhaustion in 2038.
- **Natural gas:** continued flat rate of production of 0.44 billion b.o.e./year until exhaustion in 2044.

[35] ERCB, "ST98-2013 Alberta's."

C.4. Extraction costs

Van den Bremer and van der Ploeg[36] find that, apart from the initial years 1970–75, when extraction costs were still very high as the very first exploratory and extraction activity took place, average extraction costs for Norway were US$9/b.o.e. in the period 1990–2000, US$6/b.o.e. for 2000–05 and US$14/b.o.e. for 2005–10 (2012 prices). In the absence of data for extraction costs for conventional oil in Alberta, we thus set extraction costs to $15/bbl (Canadian) for conventional oil.

Extraction costs are significantly higher for oil sands. The Canadian Energy Research Institute[37] provides estimates of the extraction costs (calculated from subtracting its estimates of royalties and income taxes from its estimates of total supply costs; see its figure E.1) for four different types of plant: 23, 36, 79 and 51 2011-WTI equivalent US$/bbl. (i.e. the price at which extraction would just become profitable ignoring tax and royalties). The Canadian Energy Research Institute[38] assumes a constant price differential of 15 US$/bbl between WTI and WCS, the price at which bitumen is sold following dilution for pipeline transportation. Ignoring diluent costs, we thus estimate extraction costs to be the average of these estimates minus the WTI-WCS price differential: 47 – 15 = $32/bbl (Canadian).

Furthermore, we note that there has been a significant increase in extraction costs in recent years. Comparing estimates of supply costs from 2012[39] of 72 US$/bbl WTI equivalent averaging across different extraction methods to comparable estimates from 2005[40] of US$35/bbl WTI equivalent reveals a twofold increase in costs in seven years (all prices are 2013 prices). To reflect this increase, we assume a linear increase from $20/bbl (Canadian) in 2006 to $32/bbl to calculate historical rents.

Due to the shale gas revolution in the U.S. and the resulting sharp decline in North American natural gas prices, many of the reserves in Western Canada are in fact not economical to extract at current natural gas prices. For natural gas, the Canadian Energy Research Institute[41] estimates extraction costs for vertical and horizontal extraction to be $7.60/mcf and $2.60/mcf or $43 and $20 /b.o.e.[42] The 2012 of natural gas is below this at $11/b.o.e. (see Figure 2). Despite the big variation of extraction estimates across different extraction methods and across different Canadian provinces ($2/mcf–$10.20/mcf or $11/b.o.e.–$57/b.o.e.) provided by the Canadian Energy Research Institute,[43] we use $15/b.o.e. corresponding to extraction costs of conventional oil.

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36 van den Bremer and van der Ploeg, "Managing and."

37 Canadian Energy Research Institute, "Canadian oil sands supply costs and development projects (2012-2046)" (2013), http://www.ceri.ca/images/stories/2013-06-10_CERI_Study_133_-_Oil_Sands_Update_2012-2046.pdf.

38 ibid.

39 ERCB, "ST98-2013 Alberta's."

40 ERCB, "ST98-2013 Alberta's."

41 Canadian Energy Research Institute, "Conventional natural gas supply costs in western Canada" (2013), http://www.ceri.ca/images/stories/ceri_study_136_-_conventional_natural_gas_supply_cost_-_final_june_2013.pdf.

42 ibid., figures 3.2 and 3.3.

43 ibid.

We thus use the following extraction costs to calculate future resource rents:

- **Oilsands:** $32 C.$ 15/bbl.
- **Conventional oil** (light and heavy crude): $15/b.o.e.
- **Natural gas:** $15/b.o.e.

For natural gas, extraction costs may exceed prices, in which case we set resource rents to zero. Since we assume that Alberta gas gets the Henry Hub price and Alberta conventional oil gets the WTI price, we effectively abstract from transportation costs. Still, transportation costs only account for a small reduction in resource rents of the order of five per cent.

C.5. Price processes

Figure C.1 shows historical records of real oil and gas prices (discounted using Canadian CPI)[44] in Canadian dollars.[45] We assume conventional oil is sold at the WTI price and natural gas at the Henry Hub NYMEX natural gas price.[46] Also shown are the longer historical records: the world crude oil price[47] and the U.S. natural gas wellhead price.[48] To calculate the value of a barrel of bitumen, the costs of diluting heavy crude to make it transportable via pipelines have to be taken into account. Western Canadian Select therefore only provides an upper bound to the actual bitumen price. The average field gate price for bitumen 9[49] provides our estimate of the actual price of bitumen.

We use the values of the mean-reversion and volatility for the oil and gas price as estimated in van den Bremer and van der Ploeg[50] (there is approximate parity of U.S. and Canadian dollars in 2013):

- **Conventional oil:** a mean price of $110/bbl, a mean–reversion coefficient of six per cent per year, and a volatility of 26 per cent.
- **Bitumen:** the same mean–reversion coefficient and volatility as conventional oil, but a substantially lower mean price of $80/bbl,[51] which assumes a constant price differential of US$15/bbl between WTI and WCS).
- **Natural gas:** a mean price of $32/b.o.e., a mean–reversion coefficient of six per cent per year, and a volatility of 20 per cent.

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[44] Statistics Canada, Cansim Online Statistics Database (2013), http://www5.statcan.gc.ca/cansim/home-accueil?lang=eng&p2=49&MM.

[45] Exchange rates from Statistics Canada, Cansim Online Statistics Database (2013).

[46] Government of Alberta, Department of Energy, Private Communication (2013).

[47] BP, Statistical Review (London: BP, 2013), http://www.bp.com/en/global/corporate/about-bp/statistical-review-of-world-energy-2013.html.

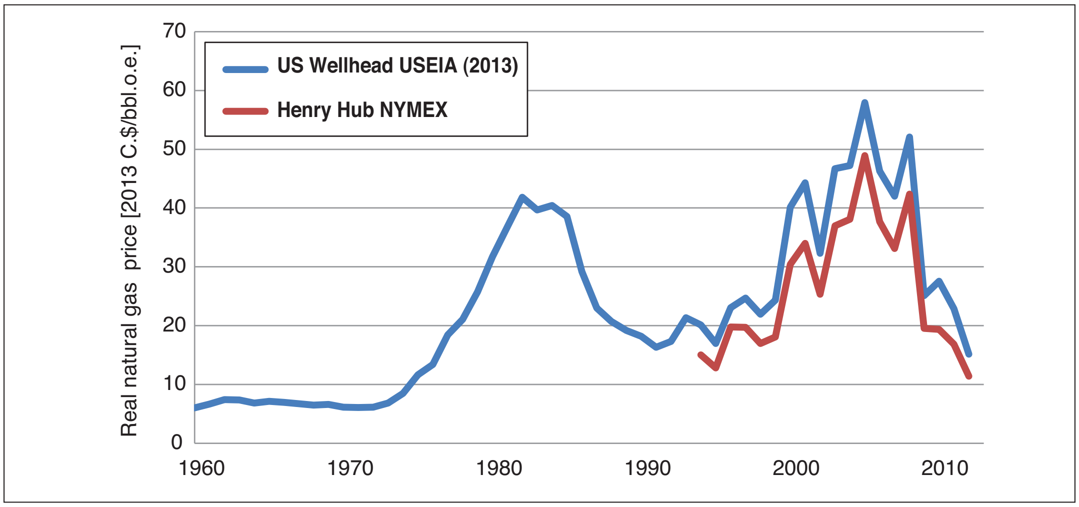
[48] USEIA, "Independent Statistics and Analysis" (Washington, D.C.: U.S. Energy Information Administration, 2013), www.eia.gov/dnav/ng/hist/n9190us3a.htm.

[49] Government of Alberta, Department of Energy (2013).

[50] van den Bremer and van der Ploeg, "Managing and."

[51] cf. CERI, "Canadian oil sands."

FIGURE C.1. REAL OIL AND NATURAL GAS PRICES (2013 PRICES)



We set the correlation coefficients between the different prices to one. The time horizon of our analysis starts Jan. 1, 2013. We use the 2012 prices as the initial prices:

- **Conventional oil:** $P_O(t = 2013) = 96$C.\$/bbl
- **Bitumen:** $P_B(t = 2013) = \$64$/bbl
- **Natural gas:** $P_G(t = 2013) = \$11$/b.o.e.

Extraction of natural gas will not be profitable in the initial years with extraction costs of 15 11C.$/b.o.e., but will eventually become profitable as a result of reversion to the mean.

All prices are in 2013 Canadian dollars unless otherwise indicated.

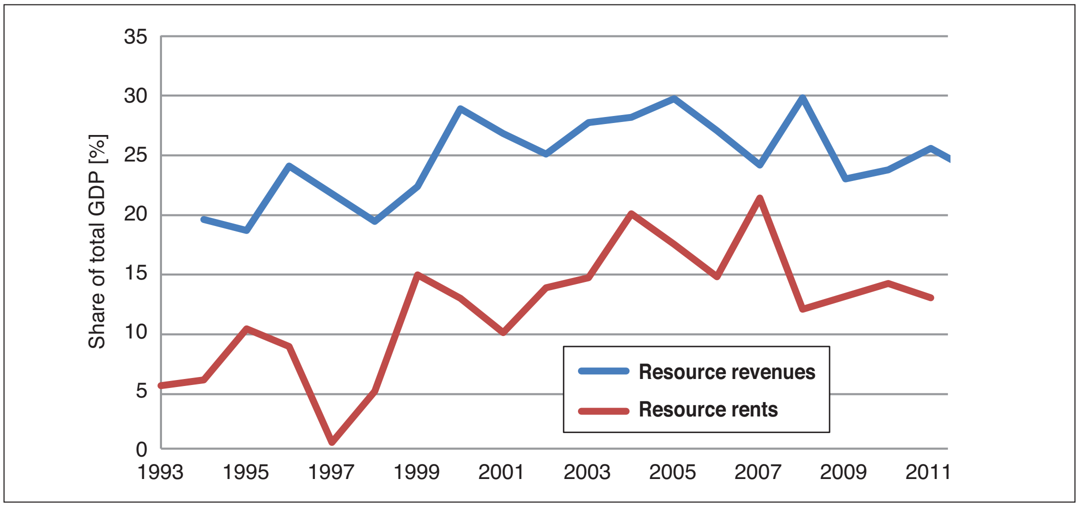
C.6. Economic and population growth

Alberta has seen relatively high rates of population growth, with a 10-year average of 2.2 per cent growth and 20-year average of 2.0 per cent growth,[52] but growth is forecasted to decline to 1.3 per cent in the next three decades. In part due to volatile oil prices, Alberta's GDP has been very volatile, with 10-, 20- and 30-year average real per capita growth rates of 3.8 per cent, 3.8 per cent and 1.4 per cent, respectively. In part these growth rates reflect the expansion of the resource-extraction sector. To calculate growth in non-resource GDP, we calculate resource rents as described above. Figure C.2 shows the share of resource revenues and resource rents of total Alberta GDP with averages of 24 per cent and 12 per cent for the range for which data is available. Subtracting resource rents gives per capita non-resource GDP growth rates of 3.2 per cent for the last 10 years and 3.0 per cent for the period for which we have calculated resource rents (17 years). Excluding not just resource rents, but total resource revenues we obtain 3.8 per cent and 3.2 per cent, respectively.

[52] Statistics Canada, Cansim.

We set trend population growth to n =1.3 per cent with population size at end of 2012 equal to 3,873,745[53] and set trend growth of non-resource GDP to $n + g$ = 3.3 per cent per year, which implies a trend productivity growth of g = 2 per cent per year.

FIGURE C.2: RESOURCE REVENUES AND RESOURCE RENTS AS A SHARE OF TOTAL GDP



C.7. Historical series of government resource rents

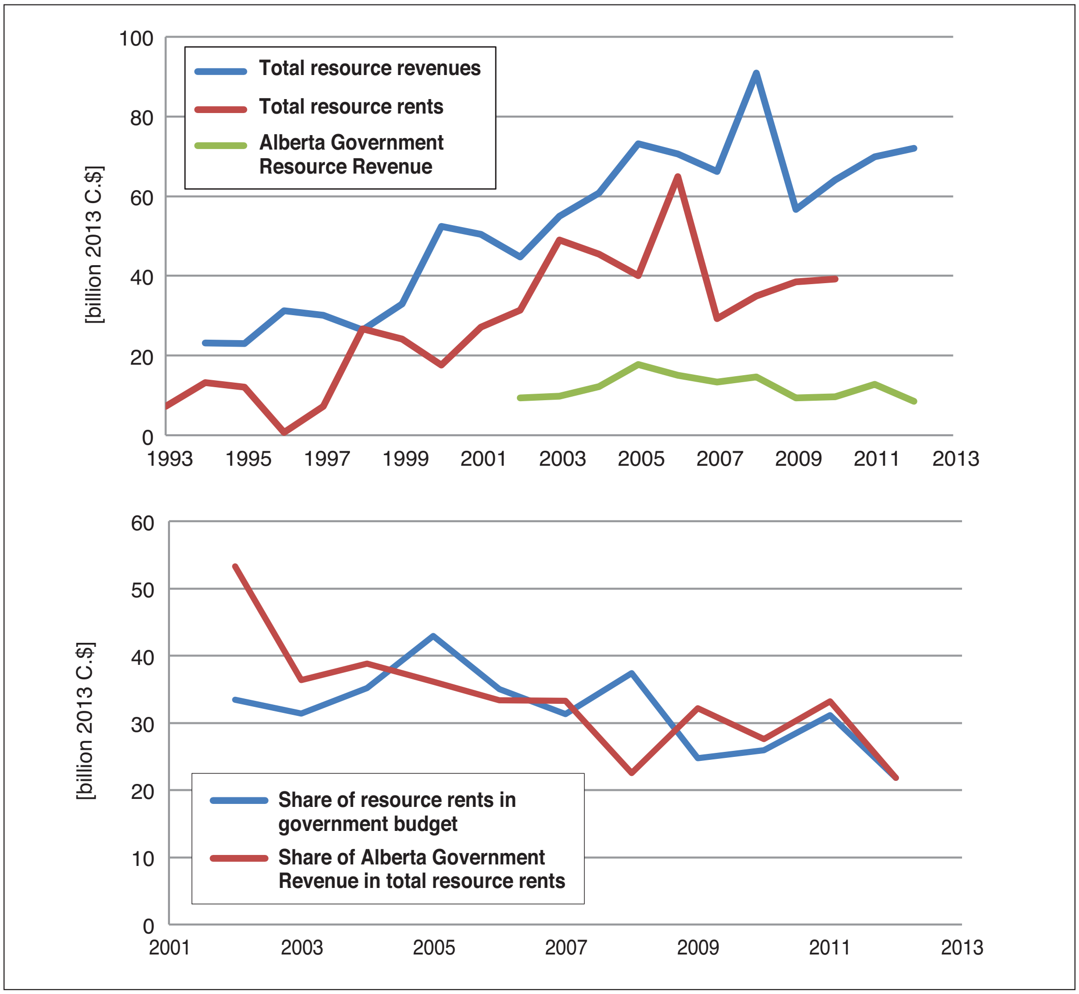
Alberta government income derived from the extraction of oil and gas and bitumen consists of a variety of fees and royalties of which the conventional oil royalty, the oil sands royalty and the natural gas and by-product royalty are the major components. In addition, the Alberta government receives a share of the corporate income tax paid by the resource-extracting sector. Figure C.3 shows the sum of these rents as received by the government in absolute values[54] and as a share of total resource rents.

On average, resource revenues constitute approximately one-third of total Alberta government revenues (part of of the income from corporate income taxation is received at a national level by the federal government). The government take (the share of total resource rents that is ultimately received by the Alberta government) is 34 per cent for the period 2002–2012. To get at optimal savings for the Alberta government, we take optimal savings for the economy as a whole and multiply it by 0.34. The government can only save that part of resource rents that it receives as royalty or tax income in the first place. We also suppose in our calculations that the size of the Alberta government relative to the total Alberta economy stays constant at 14 per cent based on an historical average.

53 ibid.

54 Government of Alberta, Treasury Board and Finance, Private Communication (2013).

FIGURE C.3: ALBERTA GOVERNMENT RESOURCE REVENUES



C.8. Initial size of the fund

We include the Contingency Account ($2.7 billion) and the Heritage Savings Trust Fund ($14.9 billion) to give a total initial fund size of $17.6 billion (5.7 per cent of total GDP in 2012) at the end of March 2013.[55] We do not include the much smaller funds, such as the Medical Research Endowment Fund and the Scholarship Fund, since these have not been funded by oil and gas revenues and reflect savings as part of the non-resource part of the economy.

55 Government of Alberta, Budget 2013, http://budget2013.alberta.ca/.

About the Authors

Ton van den Bremer is a Research Associate at the Oxford Centre for the Analysis of Resource Rich Economies (OxCarre) and a DPhil student at the University of Oxford. He holds a MEng degree in Engineering from Imperial College London and an MPhil in Economics from the University of Oxford.

Rick van der Ploeg is Professor of Economics and Research Director at the Oxford Centre for the Analysis of Resource Rich Economies in the Economics Department at the University of Oxford and the VU University Amsterdam. He is an expert in macroeconomics, public finance and international economics, with special interests in resource and climate economics. Previously he has been affiliated with Cambridge University, LSE, Tilburg University, Princeton University, University of Amsterdam and EUI, Florence, has been Member of Parliament, Chief Financial Spokesperson and State Secretary in the Netherlands, and has extensive consultancy experience with supranational and national organizations.

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