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Asymmetrical Development across Transboundary Regions: The Case of the Torres Strait Treaty Region (Australia and Papua New Guinea)

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Abstract: While there is much theoretical study of the evolution of border disparities, there is little empirical analysis of development asymmetries across border regions, and their causes or solutions. Often disparities among countries hinder the ability of transboundary agreements and other development initiatives to generate sustainable development. This study quantifies development progress amongst communities in Australia and Papua New Guinea (PNG) covered by the Torres Strait Treaty, 26 years after its inception. Using regional census data from 2011 we found contrasting patterns of human development, with markedly poorer education levels in PNG. This asymmetry was confirmed by a Human Development Index of 0.735 for the Torres Strait and 0.270 for the neighbouring province in PNG. From a survey of 1089 PNG households in 2012–2013 we calculated that 63% of people in the villages were multidimensional poor, and 28% were 'vulnerable to poverty'. Poverty was positively correlated with poor health, which has implications for the control of tuberculosis in the region. While Treaty provisions may have reduced poverty amongst some PNG villages closest to Australian communities, development initiatives by Ok Tedi mine in compensation for its environmental impacts have not. Our study highlights the causes of the sustainable development gap between PNG and Australian communities, and the necessity for transboundary agreements and institutions to have the capacity to adapt to their unintended consequences and rapid global change.

Keywords: development; treaties; international agreements; poverty; tuberculosis; transboundary; borderland; Torres Strait; livelihoods

1. Introduction

The development of many new countries' borders took place with the dissolution of the colonial empires following World War Two [1,2]. Despite the institutionalisation of new countries, the colonial empires remained the most significant regulators of economic, political, cultural and military activities [2–4]. However, borders did not always match the historical, social, cultural and economic constructs of the populations living in the borderlands, fuelling disputes and unrest within these areas [5]. Over time, cross-border disparities become expressed as development asymmetries, for example between China and its fourteen neighbours [6], and between the United States and Mexico [7].

Yet a core aim of many bi-lateral border agreements established between new neighbouring countries is to encourage a unified sustainable social and economic development of populations living

on either side of the border. However, differences in political institutions and development trajectories between neighbouring states often create unidirectional flows of people, goods and services [8], and a disproportionate occurrence of criminal activities and unsustainable practices and thus diplomatic tensions [9]. While there is much theoretical study of the evolution of border disparities, there is little empirical analysis of development asymmetries across border regions, and their causes or solutions [10].

One example of a post-colonial border agreement is the maritime transboundary region of the Trans-Fly Torres Strait, which forms the borders between Papua New Guinea (PNG), Australia and Indonesia. The Indigenous communities of the region have long-standing familial, cultural and trading linkages, but their socio-economic circumstances have diverged since PNG independence from Australia in 1975 and the ratification of the Torres Strait Treaty in 1985. At the time, the Torres Strait Treaty (henceforth 'the Treaty') was considered progressive, because it included measures to protect the livelihoods and cultures of the Indigenous inhabitants in both PNG and Australia's Torres Strait, such as free movement and marine resource utilisation for traditional purposes, and to encourage equitable and sustainable development [11]. However, there is ongoing debate about whether the Treaty has created a bridge or a barrier to the sustainable development of the populations in the region (e.g., References [12–15]).

In this paper, we address the question: to what extent has the Torres Strait Treaty enhanced equitable and sustainable development for populations living in the transboundary region of the Torres Strait? To answer this question, we first quantitatively assess development progress on both sides of the border using census data from 2011, 26 years after the Treaty's inception. As the ex-colony, we then focus on development outcomes in the PNG communities using the Multi-dimensional Poverty Index, and finally assess the relative impacts of development initiatives, including the provisions of the Treaty, on poverty. The results highlight the symptoms of asymmetric development across a border, and the necessity for transboundary agreements and institutions to be able to adapt to their unintended consequences, and rapid global change.

2. Materials and Methods

2.1. Study Area

2.1.1. The Trans-Fly Torres Strait Transboundary Region

The Trans-Fly Torres Strait transboundary region includes the northern extent of Australia (Queensland State), the south-western coast of PNG (Western Province), and the south-eastern extent of Indonesia (Papua Province; Figure 1). The Torres Strait is the narrow body of water and islands which links the Coral and Arafura Seas, and divides New Guinea from Australia. The Fly River, which forms part of the PNG-Indonesia border, discharges into the Torres Strait through an extensive delta.

The diverse coastal and marine ecosystems of the Torres Strait support a rich variety of natural resources, with hundreds of islands, reefs and mangrove forests distributed throughout the region. For centuries, the Melanesian Indigenous communities living in the current borderland region used the Torres Strait for hunting and fishing, and created strong trade connections and cultural ties which have evolved into a region-wide identity [16].

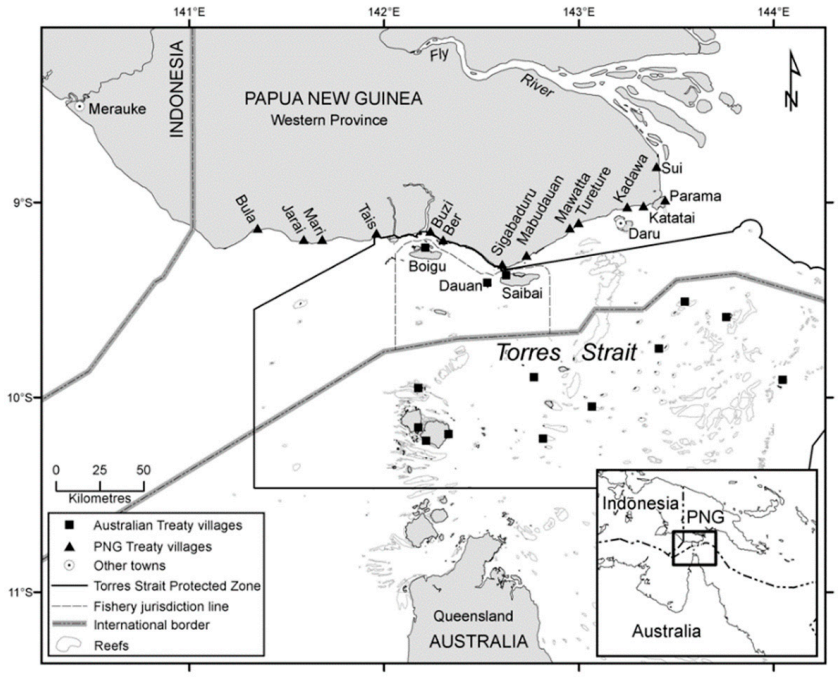

Figure 1. The Fly River-Torres Strait transboundary region, showing the Torres Strait Protected Zone and the Australian and Papua New Guinea (PNG) Treaty villages included in the Torres Strait Treaty.

2.1.2. The Torres Strait Treaty

Following PNG's independence from Australia in 1975, the Torres Strait Treaty was ratified in 1985 to manage the new international border. As Australia's closest border with Asia, the Torres Strait is strategically important for national defence, biosecurity and immigration policy [17].

Recognizing the long-established familial, cultural and trading linkages between Torres Strait Islanders and the coastal villages of Western Province, the Treaty's primary aim is to protect the way of life of the 'Traditional Inhabitants', to conserve the environment and to promote sustainable development (Torres Strait Treaty 1985). To maintain Traditional Inhabitants' livelihoods the Treaty established a Protected Zone (PZ), which includes PNG and Australian territorial waters, plus 14 of the 18 Australian Torres Strait island communities (henceforth Torres Strait Treaty communities; Figure 1). Communities from 14 PNG coastal villages, referred to as PNG Treaty villages (Figure 1) are also included in the Treaty as Traditional Inhabitants.

Traditional Inhabitants are entitled to free movement within the PZ without passports. They are also permitted to undertake traditional fishing anywhere in the PZ, defined as 'the taking . . . for their own or their dependent's consumption or for use in the course of other traditional activities, the living natural resources of the sea' (Torres Strait Treaty 1985, Art. 1(l)), but are prohibited from fishing for monetary gain without commercial fishing licenses. Traditional Inhabitants from the PNG Treaty villages can access government services (e.g., health centres) and facilities (e.g., shops, markets) in the Torres Strait Treaty communities. The Torres Strait Treaty communities closest to the PNG Treaty villages are Saibai, Boigu and Dauan, which lie within 5 km of the PNG coast (Figure 1), and these are the most frequently visited.

Although no specific standards on environmental protection and biosecurity have been included in the Treaty, Article 14 requires the two countries to 'use their best endeavours to . . . prevent the introduction of species of fauna and flora that are or may become threatened with extinction and . . . control noxious species of fauna and flora' (Torres Strait Treaty 1985). Australia's stance on this has been to adopt a very strict approach to protect its borders [18]. Villages at the border are routinely monitored by Australian officials for signs of infectious diseases, and risk-mitigation measures and

outbreak eradications are conducted at times. Restrictions on movements into the PZ of certain goods and animals are also imposed on PNG Traditional Inhabitants visiting Torres Strait Treaty communities.

2.1.3. Development History

When the Treaty was ratified differences in development levels between the Torres Strait and the South Fly were acknowledged, and effort was made to design an innovative legislative architecture which could allow disadvantaged communities in PNG to take advantage of the rich resources in the Torres Strait for their economic development [13]. Despite communities in the borderland region having long-established social and economic relationships before European arrival in the late 19th century, differences in the level of development emerged after the division of the region in 1906 between Australia and the then territory of Papua [14,15]. However, the flexibility of movement and trade across the region before the Treaty allowed the maintenance of some equilibrium in development between the two populations [14]. The advent of Aboriginal and Torres Strait Islander self-determination in 1972, and the introduction of welfare benefits for Indigenous Australians in 1974 were precursors to the current development gap, which has been widening since PNG independence in 1975 [14,15].

By 2016 there were 6626 Indigenous Australian inhabitants living within the Torres Strait Indigenous Region, which in the 2016 census included 18 Australian Torres Strait communities [19]. Between 2001 and 2012 the average population growth rate was 0.9% per annum [20]. However, the pattern was not uniform across the region, with some islands experiencing a net emigration of people which contributed to the growing diaspora in urban centres of Australia. In 2016 only 11% of the total Torres Strait Islander population was living in the Torres Strait Indigenous Region [19,21].

Torres Strait Islander livelihoods rely on a three-sector 'hybrid economy', where customary activities are complemented by a market economy and government welfare payments [22–24]. Traditional hunter-gathering remains a core component of livelihoods in order to meet and maintain cultural needs and obligations [25]. This reflects the Torres Strait Islanders' strong Melanesian identity embodied in Ailan Pasin ('Island Custom'), which differentiates them from the more numerous mainland Indigenous Australians [26]. This identity is increasingly demonstrated by the Torres Strait Islanders' aspirations for self-determination and self-governance of natural resources [27].

As for all the remote regions of Australia, special Aboriginal assistance programmes are provided along with welfare payments and government subsidies in an effort to reverse local disadvantage and the human development gap between Indigenous and settler Australians [28]. Among the assistance programmes, the Community Development Employment Projects (CDEP) scheme was introduced in 1977 to create jobs and hence reduce Indigenous employment disparity [29]. As a consequence, in 2011 22% of the Torres Strait labour force was involved in CDEP, while 42% were employed in government administration and defense [30].

The estimated population of the PNG Treaty villages in 2012 was 5616 [31]. Data for Western Province show that between 1980 and 2011 the average annual growth rate has ranged between 1.5% and 3.4% per annum [32]. Daru, the only urban centre and major market in the South Fly District, is not formally included in the Treaty, but many residents are Traditional Inhabitants who utilise resources within the PZ and visit Torres Strait islands [18,33]. The Daru population was estimated to be 15,197 in 2012 [31].

The South Fly District is at the economic and political periphery of PNG, due to the region's physical isolation and distance from major urban centres [13]. Treaty village inhabitants rely on small-scale fisheries for their livelihoods [33]. Driven by rapidly growing Asian demand, the majority of fishery catches and products (e.g., dried shark fin and sea cucumber) are traded illegally across the Indonesian border along value chains which culminate in Hong Kong, Malaysia and Singapore [34]. There is some informal trade in handicrafts into the nearest Australian Treaty communities of Saibai, Boigu and Dauan by the PNG Treaty villages closest to these islands, but commercial marketing of fish products is prohibited [35].

Since independence PNG has relied heavily on the extraction of non-renewable resources as the main source of national revenue. Extraction was allowed to occur with the proviso that profits were used to promote development in other sectors of the economy [36]. Since opening in 1984 in Western

Province, in the headwaters of the Fly River, Ok Tedi Mining Limited (OTML) has contributed close to 20% of total PNG government revenue through its exports of gold and copper [37]. In Western Province OTML has assumed the role of a 'proxy state', substituting for the provincial government in the provision of public goods and services, such as roads, schools and health services [38,39]. In 2006 the mining industry contributed up to 66% of all cash income in Western Province [40].

Despite its positive economic contribution, Ok Tedi has become an infamous example of the negative social and environmental impacts of mining [41,42]. Following the loss of a legal challenge by impacted communities for the environmental catastrophe created from the discharge of 90 million tons of rock waste per annum into the Fly River, coupled with a series of human rights abuses [43,44], in 2002 BHP Billiton transferred its 52% owner share to the PNG Sustainable Development Program Ltd., a trust fund registered in Singapore [45]. This was mandated to invest two thirds of its interest earnings into a bond to mitigate any negative impacts at the end of the mine's life. The other third was to be spent on development projects, particularly in the Fly River area affected by the environmental disaster [38]. The Ok Tedi Development Foundation (OTDF) was also established to promote 'equitable and sustainable social and economic development' of the mine-affected communities [46] (p. 43). The main community development projects implemented by OTDF were rubber plantations, improvements to *taro* production, pineapple and market gardening, barramundi processing and micro-financing facilities [46].

In 2001 the Mining (Ok Tedi Mine Continuation (Ninth Supplemental) Agreement) Act was passed by the PNG Parliament to formalise BHP's divestment and the continuation of the mine's operations until 2010. Under the Act, OTML signed six Community Mine Continuation Agreements (CMCA), and committed to spending K180 million (in addition to the royalties paid to customary landowners) to compensate the mine-affected communities, and to prohibit them from taking further legal action against OTML [47]. The CMCAs included 149 signatory villages, including the four PNG Treaty villages of Sui, Parama, Katatai and Kadawa at the mouth of the Fly River (Figure 1). Fifty-eight percent of the compensation package was provided to support development projects. The CMCAs were reviewed in 2006, and the number of signatory villages grew from 149 to 156, but did not include additional Treaty villages [38]. Altogether, these villages received an additional K350 million for the period 2007–2013 [38,46].

2.2. Data Collection and Analysis

2.2.1. Comparison between Australia and PNG

To compare human development and socio-economic conditions between the Australian and PNG communities in the borderland region, we used the 2011 national census data for both countries. In Australia, a national census is carried out every 5 years by the Australian Bureau of Statistics (http://www.abs.gov.au/). We collated data reported at the statistical unit of the Torres Strait Indigenous Region (IREG307), which includes the 14 Torres Strait Treaty communities, plus four non-Treaty island communities outside the PZ. We analysed the 2016 and 2011 data, but only the 2011 data was used for comparison with PNG [19,30].

In PNG a national census is carried out every 10 years, and the most recent was the 2011 national census collected by the PNG National Statistical Office [48]. The statistical unit used was the South Fly District, which includes all 14 PNG Treaty villages, plus Daru and 57 other villages in the Fly River delta and inland. The comparison was limited to five variables that were common to the Australian and PNG censuses: population aged $\leq$15 years, labour force, unemployment within the labour force, completion of Year 12 and school attendance.

2.2.2. Comparison amongst PNG Communities

To investigate relative human development amongst the 14 PNG Treaty villages and Daru, household data were collected between September 2012 and July 2013. The research team, consisting of six trained members of a local non-government organisation (Bata Community Development Foundation)

and two of the authors (S.B. and J.P.) visited each Treaty village and Daru six times. The local researchers were able to communicate with respondents in their local language during the survey.

A questionnaire was designed to populate indicators of living standards, education and health required to calculate the Multi-dimensional Poverty Index (MPI) at household, village and village-cluster levels [49]. In addition, questions investigated household livelihood strategies and sources of income, marine and terrestrial species harvested, and marketing strategies. The questionnaire was first tested amongst the research team, and any ambiguous wording corrected, and then translated into the local language. All respondents were asked for their free and prior informed consent, and all agreed. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the CSIRO Social Science Human Research Ethics Committee (approval 085-12).

A structured sampling design was applied to provide a representative sample of households in each Treaty village and Daru. Team members interviewed the head of every second household in smaller villages ($\leq$70 households), and every third household in larger villages (>70 households) and Daru. Following verbal consent, interviews took between 20 min and 1 h to complete.

The MPI is being adopted internationally as an improved measure of poverty and development, because it accounts for the multi-dimensional nature of poverty [49]. As such, it does not include a measure of income, but instead assesses dimensions of development related to the United Nations' Millennium Development Goals [50]. It is also versatile, since it enables a standardised comparison of poverty either amongst households, villages or broader aggregations of communities, including across countries, and it can be disaggregated to show the combinations of deprivations people experience [49].

The MPI is measured using 10 indicators (I) in three dimensions: Education, health, and living standards. In our estimation, we gave equal weight to each of the three dimensions and to each indicator within the dimension. For the estimation of the MPI, a dual cut-off is used to determine whether a household is poor. The first deprivation cut-off determines whether a household is deprived in each dimension. If the household is deprived in a certain indicator, $I_i = 1$; otherwise $I_i = 0$ (Table 1). In this way, for any household only indicators in which it is deprived contribute to the calculation of its deprivation score (c), which is the sum of weighted (w) deprivations:

$$c_i = w_1 I_1 + w_2 I_2 + \ldots + w_{10} I_{10}. \quad (1)$$

We did not collect data on the 10th indicator, malnutrition, due to a lack of expertise in the research team; instead, we assumed that malnutrition was not prevalent in the study area and assigned a non-deprivation score (0) to all households for this indicator.

Table 1. Description of the deprivation cut-offs for each Multi-dimensional Poverty Index (MPI) indicator applied in the study.

MPI Indicator	Indicator Cut-Off
1. Enrolment of children in grade 1–8 in the household	All children aged 6–17 years in the household enrolled in school
2. Schooling status of household members	At least one member of the household with five or more years of schooling
3. Child death in the house	No children have died in the household
4. Electricity in the house	Presence of fixed power or generator
5. Safe water supply	Connection to water supply or tank attached to the house regularly refilled by rain
6. Improved sanitation	Presence of barrier around the toilet, and toilet not shared to avoid contamination
7. Household building materials	House built of mosquito-proof materials
8. Household cooking facilities	Firewood is deprived, other cooking fuels not deprived
9. Household possessions	Possession of a boat with the motor in working condition and at least two communication appliances

The second cut-off determines whether a household is poor and is included in the MPI estimation. Deprivations of the non-poor are excluded from the MPI estimation in order to focus on the sub-population considered poor. Households are considered 'MPI-poor' or in 'acute poverty' when $c \geq k$ [49]. We assigned k = 3 as proposed by Alkire and Santos [49], which means that a household has to be deprived of 30% or more of the indicators in order to be considered 'MPI-poor' [51]. The household was thus considered 'MPI-poor' when $c \geq 3$. Households with a deprivation score (c) between 2 and 3 were categorised as 'vulnerable to poverty', while households with $c < 2$ were considered not poor. We used c as an indicator of poverty at the household level (henceforth 'household MPI').

At village and village-cluster levels the MPI is the product of the headcount ratio (H), which is the percentage of people who are 'MPI-poor', and the average intensity of poverty (A), which is the proportion of dimensions in which households are deprived [49]. H is estimated by dividing the total number of people in 'MPI-poor' households ($\sum q$) and the total number of people in the households at the scale of concern ($\sum n$). A is a weighted average of the deprivation score (c) of 'MPI-poor' households:

$$H = \Sigma q / \Sigma h, \tag{2}$$

$$A = \Sigma(q \times c) / \Sigma(q) \times 10, \tag{3}$$

$$MPI = H \times A. \tag{4}$$

In addition, we calculated raw headcount ratios, which are the proportions of the population deprived in each indicator.

The questionnaire data enabled a statistical comparison between household MPI and the distance from the market primary (i.e., Daru), household employment, number of income-generating activities, selling or bartering of fish, and self-assessed health status. Data consisted of continuous variables (e.g., distance from the market), binary (i.e., 'yes' or 'no'), and factors (e.g., different degrees of health status). A General Linear Model (GLM) was developed to explain which variables or factors contributed to the household MPI (Table 2). All analyses were carried out in R version 3.3.3.

Table 2. Mean, standard deviation and distribution for terms included in the General Linear Model (GLM), with household MPI as the dependent variable.

Variable Name	Data Type	Mean (or Distribution)	Standard Deviation
Deprivation	Household Multi-dimensional Poverty (composite) Index (between 1 and 10)	3.68	1.38
distPNG	Distance (km) to Daru	57.55	67.16
Empl	There is a household member who earns a salary (1 = yes, 0 = no)	0 = 918, 1 = 171	
numLiveLH	Number of income-generating activities present in the household (categorical 0)	2.57	1.01
Fishsold	The household sells the fish they catch (1 = yes, 0 = no)	0 = 202, 1 = 887	
Fishbartered	The household barters the fish they catch (1 = yes, 0 = no)	0 = 1067, 1 = 22	
Health	Health status of the household (excellent, good, fair, poor)	Excellent = 208, Good = 581, Fair = 187, Poor = 97	

2.2.3. Village-Level Poverty and Development

To assess the relative impacts of development interventions on poverty, we statistically compared the average MPIs between village clusters using a Wilcoxon test.

3. Results

3.1. Comparison between AUSTRALIA and PNG

In 2011 the proportion of the population aged ≤15 years old was higher in the South Fly District (47%) compared to the Torres Strait (37%; Table 3), suggesting a greater skewing towards children age cohorts in the South Fly. Despite the younger threshold in the South Fly District (10 years and older versus 15 years and older in the Torres Strait), the labour force was similar as a proportion (56% versus 61% in the Torres Strait). The proportion of the labour force unemployed was similar in the Torres Strait (5%) and the South Fly District (3%). In terms of education, only 1% had completed Year 12 equivalent in the South Fly, and 15% did not attend school, while in the Torres Strait 40% had completed Year 12, and only 1% did not attend school.

Between 2011 and 2016 the proportion of the Torres Strait population aged ≤15 years old declined slightly (37% and 35%, respectively). The proportion of people in the labour force decreased, while the proportion unemployed was similar. However, the education variables showed some improvement, with 43% completing Year 12, while the proportion who did not attend school remained constant at 1% (Table 3).

Table 3. Comparison of common variables recorded by the 2011 census in the South Fly District, PNG, and the 2011 and 2016 census in the Torres Strait Indigenous Region, Australia.

Variables	South Fly District 2011	Torres Strait 2011	Torres Strait 2016
Population	59,152	5921 °	6626 °
15 years old	47%	37%	35%
Labour force	56% *	61% ^	44% ^
Proportion of labour force unemployed	3%	5%	7%
Completed Year 12 equivalent	1%	40%	43%
Did not attend school	15%	1%	1%

° Aboriginal and/or Torres Strait Islanders; * population 10 years and older; ^ population 15 years and older. No demographic data or projected data for the South Fly District or Western Province are available for 2016. This limited our comparison between Australia and PNG to 2011. 2016 data for Australia is given for reference.

3.2. Comparison amongst PNG Communities

3.2.1. District-Level Poverty

A total of 1100 household questionnaires were completed, covering between 36% and 75% of households in each Treaty village. In Daru, there were safety concerns associated with entering some neighbourhoods, and, consequently, only 19% of households were surveyed. A total of 1089 useable questionnaires were included in the analysis.

Overall, 63% of the people living in the PNG Treaty villages and Daru were 'MPI-poor' with multiple deprivations in 30% or more of the indicators. A further 28% were 'vulnerable to poverty'. The remaining 9% were not poor. The MPI for all Treaty villages was 0.32. When Daru data were included, the MPI lowered to 0.28. When compared to MPI data collected since 2006 [52,53], the PNG results (including and excluding Daru) indicate that poverty was more acute than in neighbouring Papua and West Papua Provinces of Indonesia (Figure 2). Excluding Daru, the MPI was similar to that for Timor-Leste. However, the Treaty villages (including and excluding Daru) have less poverty than Niger, which is the poorest country for which MPI data exists.

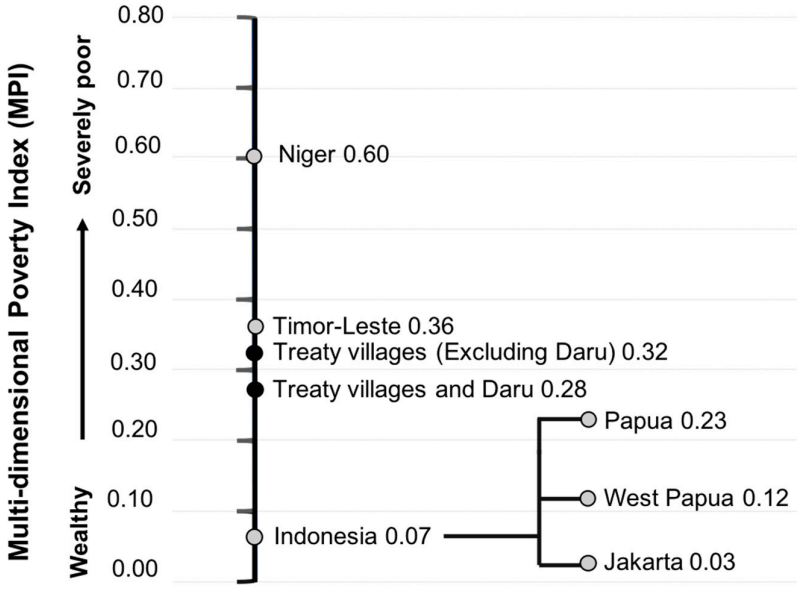

Figure 2. MPI data for PNG Treaty villages (including and excluding Daru) in 2012–2013 relative to neighbouring Indonesia and the provinces of West Papua, Papua and Jakarta (2012), plus Timor-Leste (2009) and Niger (2012). Data are from References [52,53].

3.2.2. Village and Household Level Poverty

When plotting the villages' MPI as they occur geographically from west to east, the MPI declined with increasing proximity to Daru, and then increased again (Figure 3). Amongst the Treaty villages and Daru, Daru had the lowest MPI of 0.19 (Figure 3). The highest village level MPI was observed in the western-most village of Bula (0.47). The other poorest villages were also at the extreme west and east: Mari to the west, and Parama and Sui to the east.

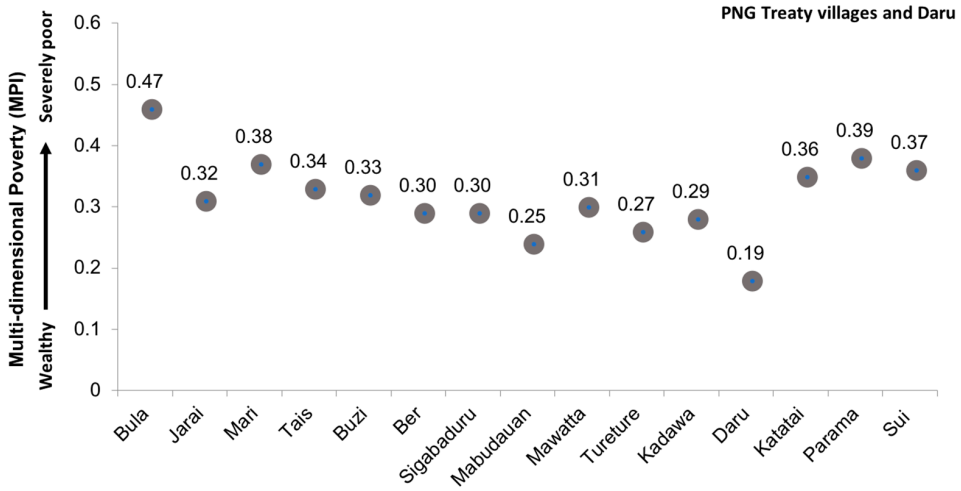

Figure 3. MPI for the PNG Treaty villages and Daru in 2012–2013. The villages are shown in geographical order from west (left) to east (right).

The GLM analysis of the relationships between household MPI and other variables or factors is presented in (Table 4). The distance to Daru was highly statistically significant ($p < 0.001$), showing that households further removed from Daru were associated with greater poverty. Moreover, the interaction between the distance from Daru and the number of income-generating activities was also significant ($p = 0.0026$), indicating that the effect of distance to Daru on the household MPI is different depending on the number of income-generating activities. Self-reported health status was a statistically significant

predictor of household MPI ($p = 0.0033$), with lower health status being associated with poorer households. Households who had a person in full-time employment were less poor, and those who sold or bartered their fish were also characterised by lower poverty levels.

Model statistics showed that the number of Fisher Scoring iterations was 2, indicating that the model converged in two iterations. However, a Hosmer and Lemeshow goodness of fit test was not statistically significant ($p > 0.05$), indicating that there was no difference between model and observed data.

Table 4. GLM results for relationships between household MPI and other variables or factors in the PNG Treaty villages and Daru (n = 1089 households).

Variables	Variable Name	Estimate	Std. Error	t Value	Pr (>|t|)
	(Intercept)	3.4152	0.2096	16.2906	0.0000
Household MPI (dependent variable)	Deprivation				
Distance (km) to Daru	distPNG	0.0088	0.0016	5.6330	0.0000
There is a household member who earns a salary	Empl	−0.5237	0.1190	−4.3996	0.0000
Number of income-generating activities present in the household	numLiveLH	0.1338	0.0562	2.3811	0.0174
The household sells the fish they catch	Fishsold	0.2640	0.0875	3.0167	0.0026
The household barters the fish they catch	Fishbartered	0.5485	0.2851	1.9241	0.0546
Health status of the household	Health	−0.1391	0.0473	−2.9411	0.0033
Interaction term	distPNG:numLiveLH	−0.0017	0.0006	−3.0244	0.0026

Model statistics: Null deviance: 2085.4 on 1088 degrees of freedom. Residual deviance: 1837.9 on 1081 degrees of freedom. AIC: 3678.4. Number of Fisher Scoring iterations: 2.

3.3. Village-Level Poverty and Development

To compare the relative impacts of development interventions and opportunities on poverty since the Treaty was ratified in 1985, we clustered villages according to the OTDF support they had received and their geographic proximity to the Torres Strait Treaty villages and statistically compared their MPIs to further assess evidence of asymmetrical development within the South Fly District. The clusters were:

- Cluster 1 'OTDF': Sui, Parama, Katatai and Kadawa, which have been targeted by OTDF with compensation and development projects as part of the CMCA since 2001;
- Cluster 2 'Treaty': Mabudauan, Sigabaduru, Ber and Buzi, which are closest to the Torres Strait Treaty islands of Saibai, Boigu and Dauan, and have the greatest access to Australian services and markets under the Treaty;
- Cluster 3 'None': Tais, Mari, Jarai and Bula (west) and Mawatta and Tureture (east), which have not directly benefitted from either opportunity.

The average MPI for Cluster 2 'Treaty' was the lowest at 0.28, followed by Cluster 3 'None' (0.34) and Cluster 1 'OTDF' (0.35). There was a statistical difference in the MPI between Cluster 2 'Treaty' and Cluster 3 'None' villages (W = 25,120, $p < 0.001$), and also with Cluster 1 'OTDF' (W = 39,954, $p < 0.001$). However, the difference between Cluster 3 'None' and Cluster 1 'OTDF' was not significant (W = 27,601, $p = 0.9871$). These results suggest that proximity to Australian government services, markets and facilities had a noticeable beneficial impact on poverty levels. However, OTDF's projects and compensation payments showed little discernible impact relative to villages that had no development interventions.

When the raw headcount ratios were compared for the three clusters, people in all three were particularly deprived of cooking fuel and mosquito-proofed housing materials (Figure 4). Cluster 1 'OTDF' was the most deprived in terms of sanitation and electricity, although they had slightly better access to safe drinking water.

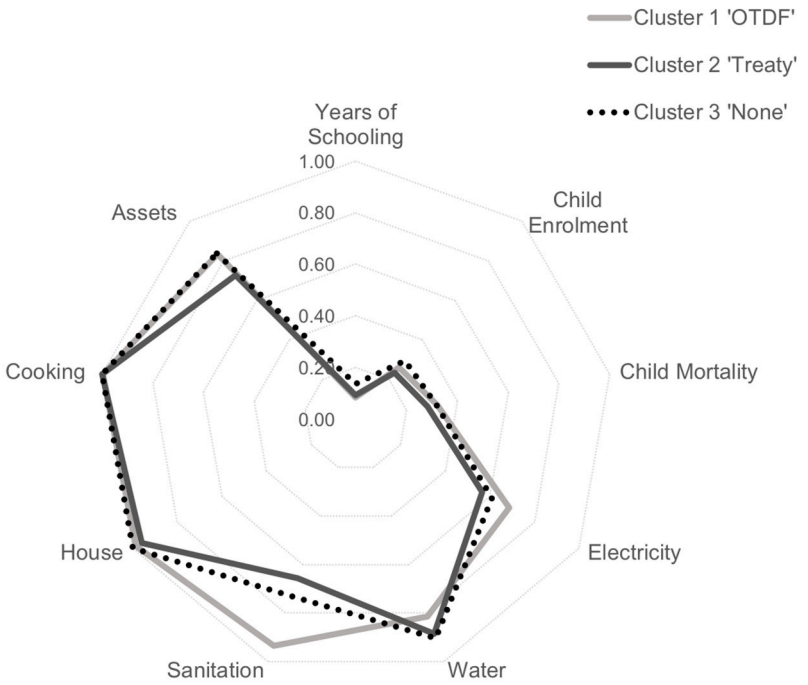

Figure 4. Spider diagram of the raw headcount ratios in each of the nine MPI indicators in the three village clusters. Cluster 'OTDF' includes the Villages of Sui, Parama, Katatai and Kadawa; Cluster 'Treaty' include the Villages of Mabudauan, Sigabaduru, Ber and Buzi; Cluster 'None' includes the villages of Tais, Mari, Jarai, Bula, Mawatta and Tureture. The intensity of deprivation increases from 0 to 1.

4. Discussion

4.1. Comparison between Australia and PNG

Although the statistical units of the Torres Strait Indigenous Region and South Fly District are geographically larger than the extent of the Torres Strait Treaty communities and PNG Treaty villages, our comparison of the 2011 census data suggests that 26 years after the ratification of the Treaty, asymmetrical development has continued in the transboundary region. Unfortunately, the quantification of the differences was limited, as only five variables were common to both censuses. However, there were notable differences between the regions in relation to education, wherein the South Fly District only 1% had completed Year 12, and 15% did not attend school, while in the Torres Strait 40% had completed Year 12, and only 1% did not attend school.

The other difference was in the proportion of the population aged $\leq$15 years old, which was markedly higher in the South Fly District (47%) compared to the Torres Strait (37%) in 2011. This indicates a skewing towards younger children in the South Fly, and therefore may be a symptom of high female fertility and rapid population growth. Data for Western Province show that in 1980–2011 the average annual growth rate has ranged widely between 1.5% and 3.4% per annum [48], casting some doubt on the accuracy of these figures [31]. By comparison the growth rate in the Torres Strait Indigenous Region in 2001–2012 was 0.9% per annum [20], which may be consistent with the lower proportion of the population being $\leq$15 years old. Directly attributing the high population growth rate in the South Fly District to a lack of development progress is difficult. However, given that globally female fertility rates and population growth are inversely related to women's education levels and employment [54], it is likely that there is a causal relationship in the South Fly.

Estimates of the labour force and proportions unemployed may be artefacts of the differences in the local economies. In the South Fly, 56% of the people aged 10 years and older were in the labour force, and of these only 3% were unemployed, but these apparently encouraging statistics may be indicative of the dual subsistence and cash economy, and reflective of high rates of engagement in daily subsistence

activities. The patterns in the Torres Strait may be explained by the presence of CDEP and other welfare payments. The marginally higher proportion of the population in the labour force (61%) in 2011 might be due to the availability of the CDEP scheme at the time, which saw 22% of the employed population involved [30]. This relationship is confirmed by the decline in people in the labour force in Torres Strait in 2016, which followed the discontinuation of the CDEP in 2015 [29]. These comparisons are further complicated by the different thresholds for the labour force applied by each census (i.e., 10 years and older in PNG, and 15 years and older in Australia). Clearly, a standardised approach to the design and collection of census data across the border region would greatly assist the monitoring of development progress in the Treaty region.

The asymmetries indicated by these limited data are corroborated by comparisons amongst the Human Development Index (HDI) data available for the transboundary region. The HDI is used by the United Nations Development Programme to rank countries according to key indicators in life expectancy, adult literacy, school enrolments and per capita income [55]. In 2011, Australia was ranked second in the world with an HDI of 0.929 [55], but Butler et al. [31] estimated the HDI for the Torres Strait to be 0.735 in 2011, which is similar to Yap and Biddle's [56] calculation of 0.737 for all Indigenous Australians. By comparison, McGillivray [57] calculated the HDI for PNG's neighbouring Western Province to be 0.260 in 2007, ranking it as one of the poorest regions in the world. These figures suggest that the asymmetry between Torres Strait and Western Province in the period 2007–2011 was equivalent to an HDI deficit of 0.475, and this is likely to be similar for the South Fly District.

The lack of development in PNG in spite of its substantial revenue from resource extraction has long been recognised [58]. Developing countries which are richly endowed with natural resources but have weak governance structures rarely benefit from mining in terms of sustainable development [59,60], a predicament often termed a 'resource curse' [61,62]. In PNG there has been a consistent decrease in living standards between 1996 and 2011. At the national level, this has been attributed to lower rates of economic growth than expected from resource extraction projects [63], and the progressive deterioration in the delivery of public services and infrastructure following decentralisation in the mid-1990s [64]. While this policy reformed the provincial government system by devolving power to local government, there was insufficient human or financial capacity to dispatch the new mandate [65]. Western Province mirrors the national situation in microcosm. Despite the presence of Ok Tedi mine, the province is one of the poorest regions of PNG [66], and human development has declined from an HDI of 0.470 in 1996 [59] to 0.260 in 2007 [57]. In parallel, development in the South Fly District has also regressed since the 2000s [67].

4.2. Comparison Amongst PNG Communities

Our results also quantify the levels of poverty in the PNG Treaty villages by applying the MPI. Overall, 63% of people were 'MPI-poor', while an additional 28% were 'vulnerable to poverty'. The MPI for all Treaty villages was 0.32, and lowered to 0.28 when Daru data were included, but it should be noted that only 19% of households in Daru were surveyed due to security concerns, excluding many of the poorer neighbourhoods, thus underestimating the Daru MPI. PNG Treaty villages were poorer than neighbouring Papua and West Papua Provinces of Indonesia, which are amongst the poorest provinces in that country, and similar to Timor-Leste, which is amongst the most deprived countries in the world [52,54], but less poor than Niger, which is the lowest-ranked country with MPI data [52]. However, these comparisons should be made with the caveat that we omitted the malnutrition indicator and instead gave a default non-deprivation score, which may have underestimated our MPI calculations.

There was also evidence of development asymmetries amongst the PNG Treaty villages. There was a clear relationship between the village and household level MPIs and distance to Daru, the primary service centre and market in the South Fly District: closer proximity meant lower poverty. Villages at the extreme west and east were the poorest, probably due to the geographic isolation, high cost of travel, limited access to public services (e.g., schools, health centres), and low opportunities for employment or

selling goods. These same geographically-isolated villages have developed a number of compensating livelihoods and employment through the sale or bartering of fish. Many households in these villages resort to the illegal harvesting and trading of marine resources, such as shark fin and sea cucumbers across the Indonesian border, to supply the growing market in Asia [35]. However, illegal fishing and trading is also evident in Daru amongst immigrants from the areas impacted by Ok Tedi mine, who have no traditional access rights to resources [35], and where the population density of >100 persons per km^2 [31] exceeds the sustainability threshold for PNG islands under current levels of technology [68].

Self-reported health status was also a statistically significant predictor of household poverty, with lower health condition being associated with poorer households. The South Fly District is a recognised global hotspot for tuberculosis (TB) and multidrug-resistant tuberculosis (MDR-TB) which is typically associated with chronic poverty [69–71]. PNG citizens suffering from TB have been flown for treatment to Australia, generating significant political attention about potential transmission of TB across the border [72]. Daru's hospital is the only diagnosis and treatment centre for TB in the South Fly District, and there is little information about the prevalence of TB or MDR-TB in the South Fly villages due to the lack of access to diagnostic and surveillance systems and health services generally [73]. Our village and household level MPI results may, therefore, be a potential predictor of the distribution and occurrence of TB and MDR-TB, on which an expansion of TB surveillance and treatment could be founded.

4.3. Village-Level Poverty and Development

The lower levels of poverty in the PNG Treaty villages which lie closest to the Australian Treaty communities suggest that the freedom of movement and access to services on these Australian islands have benefitted them. However, the relatively close proximity of the villages to Daru may also be a contributory factor. Nonetheless, it seems that the asymmetries between these PNG and Australian communities may be less than for the other PNG Treaty villages. More concerning was the apparent minimal impact of OTDF's CMCA activities on poverty in Sui, Parama, Katatai and Kadawa villages. Relative to villages in other clusters, these had the highest deprivations in sanitation and electricity. This was despite the provision of solar panel electricity to all CMCA households in 2010 [74].

Although the Treaty was hailed as highly innovative and forward-thinking in its design [11], its intention to promote equitable sustainable development for Traditional Inhabitants in the transboundary region is failing. There appear to be three primary causes of the transboundary asymmetry. First, the Treaty's conditions are rigid, and have not accounted for changes in the Traditional Inhabitants' way of life on both sides of the border [75,76]. For example, Treaty village members are only permitted to undertake 'traditional activities' in the PZ, and therefore are prohibited from harvesting or trading for commercial purposes. Yet, since 1975 the PNG government has been transitioning to a cash-based economy [77], and livelihoods in the South Fly are today dependent on earning revenue to pay for services, such as schooling and health [33]. Moreover, the strict approach to biosecurity and quarantine implemented by Australia under the Treaty limits trade into the PZ by PNG Treaty villages, and biosecurity controls limit the keeping of livestock which may pose disease risks to Australia.

Second, the Treaty enables Australia and PNG to implement co-management and catch-sharing of shared fisheries resources including prawns, lobsters, mackerel and pearl shells, which are negotiated annually. In areas of the PZ under Australian jurisdiction, the total allowable catch is divided at a ratio of 75:25 between Australia and PNG, respectively [76]. However, with the exception of lobsters, which is the major legal commercial fishery in the South Fly [33], the allowable quotas are rarely utilised by PNG Traditional Inhabitants due to their lack of capacity and capital to invest in the prerequisite fishing skills, licenses and technology (Fisheries Bi-lateral Treaty Meeting 2018). As development in the South Fly appears to be regressing, the ability of PNG communities to exploit this opportunity for commercial gain is becoming more constrained, resulting in an increased incidence of illegal fishing and trading across the Indonesian border [35,76].

Third are the two-fold effects of Ok Tedi mine, which are not directly attributable to the Treaty's arrangements but exacerbate asymmetries. Following the environmental and social impacts in the 1980s

and 1990s which resulted in the influx of non-Traditional Inhabitant immigrants to Daru and the South Fly coast, pressure on natural resources and government services has escalated, intensified by high intrinsic population growth. In turn, the OTDF and CMCA interventions have created a government substitute and de facto development aid [13]. At a higher level, OTML has acted as a 'proxy state' in Western Province, substituting for the provincial government and superimposing local and traditional authorities, leaving a void in local leadership [38]. The expectations for mining companies to act as a proxy state and service provider are common in PNG, particularly in remote regions, such as the Western Province, where the national government's capacity to deliver basic services and economic development is limited [78]. In the South Fly, the abrogation of government responsibilities has been further encouraged by the availability of Australian services to PNG Traditional Inhabitants in the Torres Strait Treaty villages [79].

5. Conclusions

Our study attempts to quantify the degree of asymmetrical development amongst communities covered by the Torres Strait Treaty 26 years after its inception, and examines the characteristics of poverty in the PNG Treaty villages and Daru. We suggest that two main avenues should be considered in order to reverse the unintended consequences of the Treaty's provisions for the South Fly District.

First, the Treaty should be revised to account for the changed socio-economic conditions that have evolved since its ratification. Currently, the Treaty has no governance mechanisms to enable this [76]. However, new forms of cross-border economic cooperation should be investigated and implemented which enable PNG Treaty villages to access adjacent Australian markets in the PZ, and further afield. Integrated economic zones in transboundary areas with economic complementarity, such as the Growth Triangles in Asia and Africa have been successful in reducing poverty of borderland populations [80,81]. As for the Zambia-Malawi-Mozambique Growth Triangle, the foundation for economic cooperation in the Fly River-Torres Strait is the countries' geopolitical proximity and their shared culture, kinship and ethnic identities [35,82], which are prerequisites for successful implementation of this concept [81].

Second, the role of OTML as a development donor and proxy government should be reconsidered. Development interventions in mining are often intended to offset the social and environmental impacts of their operations in the impacted areas, rather than being genuine attempts to catalyse development [83]. Moreover, interventions are commonly implemented without an understanding of mainstream development practice. As proposed by Banks et al. [83], any intervention should be integrated with local community and government programmes and plans, no matter how unstable these are. In this case, OTML and OTDF should be included as key stakeholders in Treaty processes and negotiations. This underscores the need for transboundary institutions, such as the Torres Strait Treaty, to become sufficiently adaptable to allow such modifications to occur in the face of unprecedented regional and global change [76].

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