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1 **The impact of a cash transfer programme on tuberculosis treatment success rate:**
2 **A quasi-experimental study in Brazil**

3
4

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32 **Keywords:** tuberculosis, social protection, conditional cash transfer, Bolsa Família, propensity
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34

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36

37 **Abstract**

38

39 **Background**

40 Evidence suggest that social protection policies such as Brazil's Bolsa Família
41 Programme (BFP), a governmental conditional cash transfer, may play a role in TB
42 elimination. However, study limitations hamper conclusions. This paper uses a quasi-
43 experimental approach to more rigorously evaluate the effect of BFP on TB treatment
44 success rate.

45

46 **Methods**

47 Propensity scores were estimated from a complete-case logistic regression using
48 covariates from a linked dataset, including the Brazil's TB notification system (SINAN),
49 linked to the national registry of those in poverty (CadUnico) and the BFP payroll.

50

51 **Results**

52 The average effect of treatment on the treated (ATT) was estimated as the difference in
53 TB treatment success rate between matched groups (i.e. the control and exposed
54 patients, n = 2167). TB patients receiving BFP showed a treatment success rate 10.58
55 percentage point higher (95% CIs: 4.39, 16.77) than TB patients not receiving BFP. This
56 association was robust to sensitivity analyses.

57

58 **Conclusions**

59 This study further confirms a positive relationship between the provision of conditional
60 cash transfers and TB treatment success rate. Further research is needed to understand
61 how to enhance access to social protection so to optimise public health impact.

62 **Summary box**

63 ***What is already known***

- 64 • While encouraging, evidence about the impact of cash transfers on TB control are still
65 scattered and conclusions are often hampered by important studies limitations

66

67 ***What are the new findings***

- 68 • This is the first study using a quasi-experimental design to evaluate the impact of
69 Bolsa Familia on TB treatment success

- 70 • TB patients enrolled in Bolsa Familia are more likely to complete their treatment
71 successfully

- 72 • Approximately half of TB patients included in this study population were not enrolled
73 in the cash transfer program despite being eligible based on the income inclusion
74 criterion

75

76 ***What the new findings imply***

- 77 • Conditional cash transfers like Bolsa Familia can contribute to TB elimination even if
78 they were not designed for this purpose

- 79 • Disparity in access is a missed opportunity to maximise TB-impact of Bolsa Familia

80 **Introduction**

81 Despite biomedical efforts, the global burden of Tuberculosis (TB) remains considerable,
82 with up to 1.5 million deaths from TB recorded in 2015. ¹ Tuberculosis treatment takes
83 many months, and a proportion of patients are not cured, either because they abandon
84 treatment, take treatment irregularly, are infected with drug resistant TB, or die before
85 completion of treatment.¹ The correlation between TB indicators and global poverty has
86 been demonstrated both at ecological and individual level, yet much of the morbidity and
87 mortality in TB patients still occurs amongst the poorest segments of the population.²
88 Social determinants impact vulnerability to TB at every stage of the disease pathway,
89 from TB infection to clinical outcomes, including whether or not the patient was
90 successfully treated.³ Ending the global burden of TB requires bold policies and
91 supportive systems able to recognise and tackle these social determinants.⁴

92
93 Recognising this social aspect of TB epidemiology, social protection is now a non-
94 negotiable component to reach the TB elimination targets set by the World Health
95 Organization, including zero households affected by catastrophic costs, defined as TB-
96 related expenditures when they exceed 20% of pre-illness annual household income.⁵
97 Brazil in particular has been an early adopter of the WHO End TB strategy,⁶ as reflected
98 by its long term efforts to integrate development and health agendas. This is partially due
99 to the long social protection tradition in Latin America, which in Brazil culminated with the
100 creation of the Bolsa Família Programme in 2003, one of the largest conditional cash
101 transfer programmes in the world.⁷

102 In 2010, the Bolsa Família Programme (BFP) provided a variable monthly stipend to
103 households meeting certain socioeconomic criteria: households earning less than 70
104 Brazilian Real a month (~22 USD at time of writing) and households with children,
105 adolescents, or pregnant women earning less than 140 Brazilian Reala month. BFP's
106 targeting is not exact, and individuals reporting an income above 140 Brazilian Realcan
107 be found in the BFP payroll.⁷ In order to receive BFP, families must be registered in the
108 Cadastro Unico (Single Registry; CadÚnico), a registry of all low income Brazilian
109 families. In return for the transfers, recipients must comply with behavioural obligations
110 (i.e. school attendance; immunization). BFP is not explicitly intended to target TB-affected
111 households and only ¼ of TB patients in Brazil appear to be enrolled in the programme;
112 given the intimate association between poverty and TB, underenrolment is likely.⁸Albeit
113 accumulating, the literature on the impact of conditional cash transfers on a variety of TB
114 indicators is still limited, and there has been little methodologically rigorous evaluation of
115 social protection interventions for TB prevention, care, and control, including treatment
116 outcomes.⁹ There has also been some support in the literature for financial incentives having a
117 small positive effect on TB outcomes,¹⁰ but the underlying philosophy, mechanisms of action, as
118 well as the ethical and sustainability implications for financial incentives may differ from cash
119 transfers embedded into proper governmental social protection platforms.¹¹

120 . Despite its scarcity, the evidence is converging upon a consistent positive impact of
121 social protection on TB epidemiology and control, including some small scale trials and
122 studies in Peru,¹² Moldova¹³ and South Africa.^{14 15 16}As for Brazil, the literature is even
123 more rich even if evidence do not necessarily follow from proper controlled trials.¹⁵⁻¹⁸
124 Torrens et al⁸ have already attempted to estimate the impact of BFP on TB treatment
125 success rates and found out that that TB patients enrolled in BFP were approximately 7%

126 more likely to be successfully treated after treatment than a control group.⁸ While the
127 findings of this study are consistent with what observed in the literature, conclusions are
128 hampered by the potential biased nature of the control group.⁸

129 For an unbiased estimate of the proportion of patients cured attributable to BFP, we must
130 construct a control group as similar as possible to the group of BFP recipients. This group
131 of BFP recipients on average have some TB treatment success rate. We wish to estimate
132 the difference in that treatment success rate if, counter to fact, that group of patients had
133 not received BFP, but had the same sociodemographic characteristics and were thus still
134 enrolled in CadÚnico.

135 To this aim, we approach the same routine data source as in Torrens et al⁸ using a quasi-
136 experimental approach to construct a more appropriate control group and to then
137 determine a more rigorous estimate of the effect of BFP on TB treatment success rate
138 amongst those who receive it. Specifically, we aimed to: 1) use propensity score matching
139 to create a control group balanced for propensity to receive BFP, 2) provide an estimate
140 of the average treatment effect of BFP on TB treatment success rate amongst recipients
141 and 3) to reflect on the utility of the resulting estimate for changing TB policy.

142

143 **Methods**

144 *Conceptual Framework - DAG*

145 A directed acyclic graph (DAG) was proposed for conceiving of the causal relationships
146 between the outcome, the exposure, and all the variables hypothesised to be on the
147 causal pathway (Figure 1). Each node in the DAG consists of a high-level construct
148 measured by proxy variables taken from the set of covariates available. The nodes in this
149 DAG were constructed based on a variety of theoretical literature, and the grouping of
150 covariates under one node denotes that they are considered to be measures of that
151 underlying construct for the purposes of this paper.^{3 19 20} Appendix 1 outlines explicitly
152 which covariates fall under each node.

153

154 The DAG outlines potential mechanisms by which BFP (“the exposure”) is proposed to
155 affect treatment success rate (“the outcome”). These include via access to directly
156 observed treatment and via increased capacity for mitigation of catastrophic costs
157 (expenditure). We provide an estimate for the direct effect of social protection outside of
158 these pathways, which may include expanded access to healthcare through means other
159 than DOT, increased psychological wellbeing, or greater integration into governmental
160 systems in general. The DAG also outlines pathways between treatment success rate
161 and income (and therefore access to BFP), through complex relationships between
162 demographics, geography, and socioeconomic factors. The ‘treatment success’ outcome
163 includes those who completed treatment with or without bacteriological confirmation.

164 *Data Handling*

165 The data for this study arose from a linkage between the 2010 TB dataset from SINAN
166 (Brazil's national Notifiable Disease Surveillance System) and the 2011 CadÚnico dataset
167 The CadÚnico dataset was itself linked to the Bolsa Familia payroll held by the Caixa
168 Federal (Federal Bank). The linkage added the demographic and social information from
169 CadÚnico and the BFP payroll to every TB patient in the SINAN dataset.

170 Ethical approval for use of the dataset was obtained by The Research Ethics Committee of the
171 Institute of Center of Health Sciences of the Federal University of Espirito Santo [protocol number
172 242,831]. Patient data did not contain identifiable information and was stored in accordance with
173 LSHTM's data governance protocol.

174 Of the complete SINAN-CadÚnico-BFP dataset ($n = 180046$), only individuals who were
175 new TB cases registered in CadUnico in 2010 with a non-missing treatment outcome
176 variable were retained for this study ($n = 16760$). Exposed individuals (defined here as
177 those receiving BFP) were further restricted to those whose receipt of BFP preceded case
178 closure. Case closure is defined as the date on which an outcome (e.g. treated,
179 unsuccessful completion of treatment, death) is recorded. The final dataset used for
180 analysis included 13,029 individuals, 6,940 of whom received BFP. The dataset contained
181 a set of 60 covariates that could be used for propensity score matching (i.e. categorical
182 or numerical data).

183 Many of these 60 covariates had a considerable amount of missing data. Data was
184 assumed to be missing completely at random. Variables that were recorded as missing
185 in over 50% of individuals were omitted from the analysis. These variables included house
186 type (permanent/improvised), roof, floor, and wall material, number of people and families
187 in the home, number of bedrooms and bathrooms, variables relating to employment
188 status, expenditure on rent and transport, and receipt of pension, unemployment benefit,

189 and alimony. It is conceivable that rent and transport expenditure could be important
190 confounders of treatment success rate given the potential of cash transfers for mitigating
191 catastrophic costs, but neither are conditionally associated with both outcome and
192 exposure in the observed data and expenditure is represented by other retained
193 variables.²¹

194
195 The omission of variables with this level of missing data resulted in 45 covariates to be
196 considered for use in propensity score estimation. A sensitivity analysis was run omitting
197 all variables with over 25% missing data, which further omitted water expenditure and
198 years of formal education. At both missing data thresholds, at least one proxy covariate
199 remained under each node of the DAG such that no high-level construct was
200 unrepresented by the available covariates.

201
202 *Propensity Score Matching*
203 Without applying propensity score approaches or other approaches to control for
204 confounding, it is likely that the values of the available covariates between the exposed
205 and the unexposed (and those who experience or do not experience the outcome) vary,
206 which potentially biases comparisons between groups. We wish to achieve a 'balance' in
207 these values, that may approximate the balance produced by conventional randomisation
208 procedures. We wish to first determine the likelihood of receiving BFP given the covariate
209 values, which is represented by the propensity score. If the propensity score is then
210 balanced between groups by matching, it is as though the covariates that were used to
211 estimate the propensity score were themselves balanced.²²

212 Propensity scores were estimated by logistic regression. One of two criteria must be met for
213 a variable to be included in this logistic regression: a) conditional association with the outcome
214 given exposure, to improve precision or b) both association with exposure and conditional
215 association with outcome given exposure, to account for confounding.²³ These criteria apply to
216 both mediators and confounders and can be determined from the DAG (Figure 1). All
217 DAG nodes meet these criteria but housing and thus the covariates used to model the
218 propensity score were all non-housing covariates meeting the missing data threshold.
219 Quadratic forms of the continuous covariates were used in the logistic regression but
220 sensitivity analyses were performed without including them. Two-way interactions
221 between gender and all variables and age and all variables were also used, given it is
222 likely that these covariates would differ in effect across strata.

223

224 Each patient who did not receive BFP (i.e. not exposed) was matched to a patient who
225 did receive it (i.e. exposed) closest in propensity score, within a particular 'caliper' of 0.1
226 standard deviations from the mean propensity score. Matching was done with
227 replacement and multiple matches to minimise both bias and variance, following Caliendo
228 & Kopeinig (2008).²⁴ Multiple matches were weighted to form one matched control for
229 each patient. Standardised mean differences and overlap plots were examined to assess
230 whether balance was improved by matching.

231

232 Throughout the literature, complete cases are used for propensity score matching, and
233 this is the approach used in this paper.²⁴ This reduced the dataset to 2167 individuals at
234 the 50% missing data threshold and 3048 individuals at the 25% threshold.

235

236 *Estimating the Impact of Bolsa Familia*

237 Taking the difference of the proportion of treatment successs between matched groups
238 resulted in an estimate of the average effect of treatment on the treated (ATT), or the
239 (causal) risk difference in the exposed. The procedure used in Abadie & Imbens (2011)²⁵
240 was used to estimate the standard error of the ATT and thus the confidence intervals.
241 The confidence intervals thus account for the uncertainty due to the matching procedure,
242 but do not account for the uncertainty due to the fact that the estimated propensity score
243 is itself a function of the data; this latter feature leads to conservative inferences.²⁵ The
244 ATT was also estimated by a multiple imputation based sensitivity analysis, and point
245 estimates from this are provided for comparative purposes in Appendix 2.

246

247 *Statistical Software*

248 All analyses were conducted in R v3.4.1 and the MatchIt package was used for the
249 propensity score matching procedure.

250 *Role of the Funding Source and conflict of interest*

251 This work was sponsored by a grant from the Wellcome Trust to the PI (n. 104473/Z/14/Z).
252 The funders had no role in study design, data collection and analysis, decision to publish,
253 or preparation of the manuscript. Authors declare no conflicts of interest. The
254 corresponding author had full access to all the data in the study and had final
255 responsibility for the decision to submit for publication.

256 **Results**

257 *Propensity Score Matching – Covariate Balance*

258 A complete balance table is presented in Table 2 in Appendix 1 for the match produced
259 by Model A for all covariates included in the propensity score matching exercise. There
260 is good similarity of the covariates after matching, suggesting a reasonable balance was
261 obtained between groups. Prior to matching, there were some imbalances found between
262 BFP recipients and non-recipients on important covariates. Figure 2 presents the changes
263 in standardised mean difference between those receiving BFP (i.e. exposed) and those
264 not receiving BFP (i.e. not exposed) before and after matching. Figure 3 presents overlap
265 plots to demonstrate the similarity of the propensity score values between groups.

266 Propensity score matching in general resulted in improved balance of the values of
267 covariates between cases and controls. A standardised mean difference of below 0.1
268 implies that groups do not differ greatly between values of the covariate.²³ Though the
269 matching process only brought 50% of the imbalanced variables below this threshold, a
270 large improvement was seen on the balance of important upstream covariates like age
271 (0.42 to 0.01), income (0.40 to 0.09), and schooling (0.24 to 0.12). The change in
272 distributions of these variables after matching can be seen in Figure 3. On average, those
273 receiving BFP in the unmatched cohort were younger (34.5 vs. 41.3 years), poorer (65.2
274 vs. 197.4 Brazilian Real per month), and less educated (89.2% vs 83.5% not completed
275 secondary school).

276

277 From Figure 3, 20.9% of TB patients fall under the 70 Brazilian Real income threshold for
278 unconditional receipt of BFP and therefore are theoretically eligible for the programme,

279 but yet excluded from it. A further 29.4% fall under the 140 Brazilian Real income
280 threshold and could therefore potentially be eligible for BFP.

281

282 *Estimating the Impact of Bolsa Familia*

283 In total, four estimates of the ATT were produced (Table 1). Model A is the primary model
284 of interest as it is the most complex model specification. Models B-D represent sensitivity
285 analyses on Model A to investigate how sensitive the results are to simplifying changes
286 to these modelling and missing data decisions.

287

288 The average effect of treatment on the treated from Model A was estimated to be 10.58
289 (95% CIs: 4.39, 16.77) (Table 1). Thus, amongst TB patients who receive BFP, we expect
290 a treatment success rate 10.58 percentage points higher than if those patients had not
291 received the benefit. The proportion successfully treated in those who did not receive BFP
292 was 76.6% compared to 87.2% in the BFP recipients. This average treatment effect is
293 protective even when a simpler model is used and when the missing data threshold at
294 which covariates are omitted is reduced to 25%, with ATT estimates between 6.31 and
295 7.21 (Table 1). It is also in broad agreement with an ATT point estimate of 7.22 obtained
296 from a multiple imputation approach (Appendix 2). Expressed as number needed to treat
297 (NTT), the estimated ATT implies that on average, amongst TB patients who received
298 Bolsa Familia before acquiring TB, one unsuccessful treatment outcome was averted
299 because of Bolsa Familia for every nine patients.

300

301

302

303 **Discussion**

304 *Summary – Interpretation of Results*

305 This is the first study that uses a quasi-experimental approach to estimate the impact of
306 a conditional cash transfer programme on TB treatment success rates.⁹ Across all
307 models, results have shown a substantial absolute increase in TB treatment success rate
308 (between 7-11%) amongst those who receive BFP. This seems to suggest a consistent
309 positive association between receiving BFP on a key indicator of TB control: treatment
310 success rate. This is in line with Torrens et al. (2016),⁸ Durovni et al. (2017)¹⁵ and a few
311 other previous studies evaluating the relationship between social protection and TB
312 outcomes undertaken using less rigorous methodologies and adjusting for only a subset
313 of potential confounders, which also demonstrate a protective effect of similar scale.^{13 26}
314 Given the already relatively high treatment success rate in Brazil, it can be expected that
315 the size of impact may be even higher in settings within and outside Brazil, with lower
316 treatment success rates and a less effective TB control program. Similar propensity score
317 approaches have already been used to evaluate the effect of cash transfers in HIV/AIDS,
318 but not on TB.²⁷

319 Another important and somewhat unexpected finding of our analysis is that the profile of
320 TB patients enrolled in BFP was not overtly dissimilar from TB patients that have not
321 received BFP even before matching. Figure 2 suggests that the most imbalanced
322 covariates for receipt of BFP (based on the standardised mean difference) were state of
323 residence, income, age, and schooling. There may also be differences between recipients
324 and non-recipients based on measures of the infrastructure of the local area (sewage,
325 electricity, trash disposal). TB patients not benefiting from BFP transfers appear to be

326 broadly similar to TB patients who are BFP recipients under a number of other
327 sociodemographic characteristics, particularly on comorbidities such as diabetes and
328 alcohol abuse, as well as on DOT prevalence (Table 1 in Appendix 1). This suggests
329 there may be some shared vulnerability amongst TB patients (i.e. concomitant
330 socioeconomic stressors, diverse ability to navigate complex social services), that are not
331 captured by the current BFP targeting and enrolment process, leading to some degree of
332 disparity in access to social protection and specifically BFP in Brazil. Even when looking
333 strictly to the BFP eligibility criterion (i.e. income), our results show that up to 51.3% of
334 patients may be theoretically eligible for BFP, but yet left out. This seems to further
335 suggest that the income threshold for BFP is insufficiently specific to ensure access to
336 vulnerable TB patients.

337

338 *Strengths & Limitations*

339 The utilisation of quasi-experimental approach is a major strength of this paper. Quasi-
340 experimental approaches like propensity score matching require fewer assumptions
341 about the data than traditional parametric counterparts. The specification of the estimand
342 and population parameters of interest are an additional strength to using propensity score
343 matching, and the risk of bias from residual confounding is minimised compared to prior
344 work by careful use of a DAG.²⁸ While the use of propensity scores for matching has
345 recently drawn some criticism,²⁹ the diagnostic plots demonstrated in Figures 2 & 3 show
346 that balance was improved by matching, and a number of model specifications for the
347 propensity score were tested and found to demonstrate a similar positive impact.

348 Indeed, a clear strength of this work is the comparability of the control group. As
349 demonstrated in Figure 3, those in the exposed group and those in the control group have
350 a very similar distribution of propensity to receive BFP. This overlap suggests that we are
351 only comparing patients with similar covariate profiles: while some of the control patients
352 may not be eligible on paper for BFP, in the complex context of real-world receipt of BFP,
353 the not-exposed group (our 'control' group) resemble almost exactly those TB patients
354 who receive BFP on all measured variables and are representative of a broad range of
355 TB patients from across Brazil. This is a methodological improvement over the control
356 groups seen in prior work which greatly strengthens the quality of evidence available to
357 policymakers.

358

359 The control group in Durovni et al¹⁵ was taken from a pool of all TB patients rather than
360 those who are registered in CadÚnico, and therefore some patients ineligible for BFP
361 were included in the control group. The control group in Torrens et al⁸ was taken from TB
362 patients who were eligible in theory for BFP, but who had not received any money from
363 the programme until after treatment. This control group had different characteristics to
364 those TB patients not eligible for the programme on demographic and socioeconomic
365 variables examined by the authors. Both of these control groups may have potentially
366 biased the resulting estimate of proportion of patients cured attributable to BFP.

367 This quasi-experimental approach also implies the possibility of drawing causal
368 conclusions. The estimand used in this study, the average treatment effect on the treated,
369 could be given a causal interpretation if particular 'identifying' assumptions hold, including

370 i) positivity, which implies that no individual has a probability of 1 of receiving BFP
371 conditional on their confounders, ii) consistency, which implies that different variations of
372 receiving BFP do not have different effects on TB outcomes, and iii) conditional
373 exchangeability, which implies that there is no residual confounding. We note that while
374 BFP might appear to create a structural violation of the positivity assumption with its
375 income threshold, examining the threshold itself it was noted that the cutoff was often
376 inaccurately applied and thus very few random positivity violations were encountered in
377 the matched set. With regards to the consistency assumption, we specifically assumed
378 that receipt of any amount of transfer for any amount of time was sufficient in this context,
379 but further work should investigate dose-response relationships between cash transfers
380 & TB. Drawing causal conclusions is however hampered by the non-interference
381 assumption, which in this context assumes that the exposure received by one individual
382 does not affect the outcome of the other. The results of this study suggest that the size of
383 effect found may be too large to ignore this assumption and work should be undertaken
384 to investigate the effect of social protection on TB transmission. Another potential violation
385 of this assumption is that BFP increases the probability of treatment success not only in
386 recipients but also in other cases through community effects of the cash transfer.

387 In conclusion, while most identifying assumptions are potentially plausible, we cannot
388 draw conclusions about causality given the interference limitations outlined above. The
389 circumstances under which causal inferences can be drawn with interference is an area
390 of ongoing research.³⁰

391 Another limitation to this work is the data quality. The missing data results in a relatively
392 small sample size used for matching and we cannot rule out the possibility of residual

393 confounding from covariates that are mostly missing or remain unbalanced. Remaining
394 imbalance on the state variable suggests data may be missing conditionally at random
395 on the state variable. As information on it is housed within a separate register, we were
396 unable to assess the impact of the Family Health Strategy, though previous work
397 suggests the effect of BFP is independent of FHS coverage.¹⁵ While an approach
398 combining multiple imputation and propensity score matching would have mitigated this
399 problem, there remain many gaps in the literature on the practical implementation of these
400 techniques together (see Appendix 2). Furthermore, the data linkage is cross-sectional
401 and thus time-varying confounding cannot be accounted for with these data; better data
402 availability longitudinally would allow for measurement on more direct measures of TB
403 control, such as incidence.

404

405 The choice of a dichotomous outcome variable may be another limitation: non-success
406 outcomes include continued disease post regimen completion, treatment abandonment,
407 death from TB, death from other causes, and development of MDR-TB, which may have
408 heterogeneous risk factors. Loss to follow up and transferred cases are also not
409 considered by this analysis – the analysis is agnostic about whether these patients were
410 cured or not cured. The results may be different if each non-success outcome were
411 addressed in turn, but this would require a larger sample size and may be best addressed
412 in a descriptive study.

413

414 *Policy Implications*

415 Despite the above limitations, these findings preliminarily suggest that: 1) there is a
416 considerable proportion of TB patients eligible for BFP that for unknown reasons seem to
417 be left out from the programme; 2) almost half of the TB patients will not be eligible for
418 BFP according to income thresholds, and thus there is room for a more comprehensive
419 or multidimensional targeting approach not only using income as eligibility criteria. Given
420 the 7-11% absolute increase in treatment success rate seen amongst those receiving
421 BFP from our work, from a health rights perspective, it must be considered how best to
422 deliver a protective programme to vulnerable patients in Brazil.

423

424 BFP was not designed to address specific diseases, not least TB: TB status is not a
425 targeting criteria and none of the conditionalities currently imposed by the program have
426 any direct implication for TB care and/or TB control. Despite the suggested positive
427 impact, ethical and equity issues make unlikely that TB will become one of the eligibility
428 criteria of BFP. Nonetheless access could be expanded, and thus impact maximised, by
429 making BFP more TB-sensitive through a more inclusive, albeit non-stigmatising,
430 targeting strategy. Higher impact could in fact be achieved by simply ensuring that
431 patients that are already eligible by definition for the programme receive the benefits, or
432 at least receive them while on treatment. To this purpose, further research is urgently
433 needed to understand determinants of access to BFP from TB patients and to explore
434 those supply and demand side barriers that delay the transfer of benefits once TB-
435 patients are legitimately enrolled.

436 Understanding how to effectively and cost-effectively remove these individual and system
437 level barriers and what may be the ultimate impact on the Brazilian TB epidemic is a
438 priority research area, whose lessons may be transferrable to other settings.

439 Nonetheless, it can be anticipated that the removal of these barriers may require the
440 implementation of more efficient BFP delivery models, including the ‘single window’
441 approach which entails an integrated delivery of TB care services and social protection.³¹
442 According to this model, the access to the most appropriate social protection schemes is
443 determined and facilitated at the primary health care level where ad hoc staff (e.g. social
444 workers) are trained to assess the social protection needs of TB patients and provide
445 information, legal and administrative advices, and referrals to various services so to allow
446 patients to access benefits from one ‘single window’ without having to navigate across
447 complex and multiple service points.³¹

448

449 Another emerging model for the delivery of social protection is the ‘cash plus’ model in
450 which the provision of cash transfers is combined with another form of social support
451 when the provision of in kind benefits is not deemed sufficient to reduce households’
452 vulnerabilities (including health related vulnerabilities).³²

453

454 In the case of TB in Brazil, this ‘plus’ component can be represented by a top up of the
455 cash benefit to account for the TB-related catastrophic costs incurred by the households;
456 or the provision of a food basket to improve nutrition of cash beneficiaries and therefore
457 their treatment outcome; or the improvement of housing and ventilation conditions to
458 interrupt intra-household transmission of TB. To identify the most relevant ‘intensifier’ of

459 any cash transfer intervention it will be essential also to understand thoroughly the most
460 likely pathway through which this impact takes place. This requires the development of a
461 setting-specific, epidemiologically driven conceptual framework and a more
462 comprehensive collection of data for the variables in the causal pathway.

463 To be useful the above research agenda should rely on both quantitative and qualitative
464 methods to embrace the complexity of pathways likely to underlie impact and the multi-
465 faced nature of determinants of access to cash transfers in the context of TB-affected
466 communities.

467

468 *Conclusions*

469 Overall, the strength of evidence and size of effect of the ATT estimated in this work
470 seems to suggest that expanding social protection to a wider population of TB patients
471 may represent a valid mechanism for improving TB outcomes beyond the traditional
472 biomedical approach. This is consistent with the need of a multisectorial accountability
473 framework expressed during the last WHO- Global Ministerial Conference held in Moscow
474 on November 2017 which demands a more pervasive integration of TB programmatic
475 action within development models and infrastructures.³³ It is essential that, like in this
476 work, recent developments in quasi-experimental methodology continue to be integrated
477 with the evidence base for bold policies in development. With stronger evidence available,
478 the rapid implementation of bold policies may be justified in TB contexts and the global
479 public health community will be a large step closer to achieving the aims of the WHO's
480 End-TB Strategy.

481 **Competing interest declaration**

482 The authors declare no competing interest.

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581 **Table 1. Results of propensity score matching estimates of the ATT for four models.**
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Models* n controls = 898 n exposed = 1269	ATT¹	95% Confidence Intervals	N Controls Matched (unweighted)	N Exposed dropped	N Pairs Matched (weighted)	N Unique Controls
Model A	10.58	(4.39, 16.77)	6021	109	1160	545
Model B***	7.21	(1.33, 13.09)	6468	21	1248	656 _[D2]

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Models** - n controls = 1319 n exposed = 1729	ATT¹	95% Confidence Intervals	N Controls Matched (unweighted)	N Exposed dropped	N Pairs Matched (weighted)	N Unique Controls
Model C	6.31	(1.46, 11.16)	8895	70	1659	955
Model D***	7.06	(2.57, 11.56)	9272	17	1712	1001

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585 *Model A includes linear and quadratic forms of continuous covariates and omits variables with >
 586 50% missing data to estimate the propensity score. Variables included in the final propensity
 587 score are those listed in bold in the caption to Figure 1.

588 ** Models C & D omit variables with > 25% missing data

589 *** Models B & D omit quadratic forms of continuous covariates

590 ¹ ATT= Average effect of Treatment on the Treated.

591 The matching used was many-to-one with replacement. Some exposed patients were not similar
592 enough to any control patients according to the caliper threshold and these individuals were
593 dropped from the analysis (N Exposed dropped). Some controls were not similar enough to any
594 exposed patients and were thus not used as potential matches and dropped from the analysis.
595 The remaining controls (N Unique Controls) were then 'copied' a number of times to be used as
596 potential matches (N controls matched unweighted). Each control was not matched individually,
597 but rather weighted to form one matched comparator for each treatment patient. These matched
598 comparator patients were matched to the treatment patients to form matched pairs (Pairs of
599 controls and treated cases matched). The number of pairs may thus be higher than the total initial
600 sample size as some controls were used more than once and some were not used at all.
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602 Figure 1. DAG outlining the pathways linking Bolsa Familia with TB outcomes.

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A directed acyclic graph (DAG) was built to conceptualise the potentially causal relationships between constructs relevant for measuring the impact of Bolsa Familia on TB treatment success rate. Red nodes are ancestors of both the outcome and the exposure (i.e. confounders) while grey nodes are unassociated with the outcome and exposure. Blue nodes are ancestors of the outcome.

The DAG links nodes that represent constructs that are measured by covariates (Table A).

TABLE A

Node (Construct)	Covariates Included in Model	Covariates Excluded from Model (Missing Data Threshold)	Covariates Excluded from Model (No Available Measure)
<i>State</i>	State		
<i>Race</i>	Race, Indigenous, Quilombola		
<i>Local Area</i>	Urbanicity, Running Water, Sewage, Electricity, Water Store, Garbage Collection	House Type	Transit Access
<i>Education</i>	Years of Education, Literacy		
<i>Socioeconomic Vulnerability</i>	Child Work, Institutionalisation, Work-Acquired TB	Employment, Pension Receipt, Unemployment Benefit, Alimony Receipt	Food Security, Adequate Nutrition, Perception of Poverty
<i>Age & Sex</i>	Age, Sex		Gender Identity
<i>Comorbidities</i>	AIDS, Alcohol Use Disorder, Diabetes, HIV, Mental Disorder, Other Chronic Illness		General Mental Health, Stress
<i>Income</i>	Income		
<i>Expenditure</i>	(on) Food, Energy, Gas, Water	(on) Rent, Transport	Medical Costs
<i>Health Seeking Behaviour</i>	Directly Observed Treatment		Engagement with Primary Care
<i>TB Form & Severity</i>	Chest X-Ray, Initial Sputum Smear, Pulmonary/Extrapulmonary, Throat Culture, Tuberculin Skin Test		MDR TB (is included in outcome as non-successful treatment)

<i>Drug Regimen</i>	Rifampicin, Isoniazid, Ethambutol, Streptomycin, Pyrazinamide, Ethionamide, Other Drugs		
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620 Not all covariates included under one of the constructs in the DAG were included in the propensity
621 score model. Table A summarises which covariates were included and which were excluded.
622 Some covariates that might reasonably be part of the pathways encoded in this DAG were
623 excluded as there was no adequate measure of them in this linked administrative data. Other
624 covariates were excluded by the missing data threshold, which itself was chosen to balance
625 measurability of each of the constructs with the loss of sample size from undertaking a complete
626 case analysis.

627
628 The Housing Quality node was not included in the model as it was not associated with outcome
629 (TB mortality) or exposure. The Housing node included measurable covariates of roof, floor, and
630 wall material, number of people in the home, and the number of bedrooms and bathrooms, as
631 well as the unmeasurable covariate of indoor air pollution.
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633 Figure 2. Standardised Mean Difference

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The change in standardised mean difference in the matched and unmatched groups for each variable. A smaller difference indicates improved balance between groups; being below the threshold of 0.1 is conservatively considered to be effectively balanced. Balance has been largely improved by matching though some imbalance remains between groups. [Labels: exp = expenditure; thorax = chest X-ray; bacilo.i = initial sputum smear; throat = throat culture; tst = tuberculin skin test; mental = mental disorder; disorder = any other chronic illness; iso = isoniazid; eti = ethionamide; rif = rifampicin; pir = pyrazinamide; est = streptomycin; eta = ethambutol]

662 Figure 3. Overlap in estimated propensity scores between those receiving and those not
663 receiving BFP before matching (top left) and after matching (top right)

664 Before Matching After Matching

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675 Overlap has been substantially improved by matching to treated (exposed) patients,
676 suggestive of the groups being balanced on the propensity score. The region of overlap
677 extends between 0 and 1. Also presented are similar plots of variable distribution before
678 and after matching for income, age, and schooling (from top to bottom). Dotted lines on
679 the income distributions mark the thresholds for BFP eligibility.

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681